GROUND WATER

in the

BALTIMORE INDUSTRIAL AREA

MARYLAND STATE PLANNING COMMISSION

MAY 1945

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BALTIMORE INDUSTRIAL AREA

Prepared by

JOHN C. GEYER

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MARYLAND STATE PLANNING COMMISSION

BALTIMORE, MARYLAND-18
Room 20 Latrobe Hall
The Johns Hopkins University

May 15, 1945

The Honorable Herbert R. O'Conor
Governor of Maryland
Annapolis, Maryland

My dear Governor O'Conor:

I am pleased to transmit herewith a copy of a report by Mr. John C. Geyer on ground water in the Baltimore metropolitan industrial area.

This study, conducted over the past two years, has been made available to the Commission without any cost to the State. This was made possible principally because the data from which Mr. Geyer assembled this material came from personal files and those of large industrial plants.

This reservoir of data should prove extremely helpful and valuable to existing industrial establishments and gives some indication as to the water possibilities for prospective industries in the area.

I wish to acknowledge here the Commission's appreciation to Mr. Geyer for his excellent work.

Very truly yours,

Abel Wolman

Abel Wolman
Chairman

May 15, 1945

Dr. Abel Wolman, Chairman
Maryland State Planning Commission
The Johns Hopkins University
Baltimore-18, Maryland

Dear Dr. Wolman:

I have the pleasure of submitting herewith a report on the ground water situation in the Baltimore industrial area.

Wells belonging to the industries in and around Baltimore supply some 40 million gallons daily of ground water, an amount equal to one third the total quantity of water normally used by the City of Baltimore. These artesian ground water supplies are in danger of destruction by leakage of shallow salty water down both used and abandoned wells. Should continued deterioration force the abandonment of these supplies, the loss to the City of Baltimore, its industries and people will be around $1,000,000 annually. The danger of losing these supplies can be greatly reduced if cement grout is properly used to construct, repair and seal wells. A comprehensive program of record keeping and analysis is needed for planned conservation. This work is now going forward under the joint sponsorship of the Maryland State Department of Geology, Mines and Water Resources in cooperation with the United States Department of Interior, Geological Survey.

Indebtedness is acknowledged to all governmental organizations, private industries, and individuals who, through the course of the years, have recorded observations, analytical data, or the results of studies connected with the development and utilization of ground water in the Baltimore industrial area.

Especial appreciation is expressed to the industries of the area who have freely furnished information concerning their wells, and who have cooperated patiently throughout the course of the work.

A debt of gratitude is acknowledged to the following men for their many helpful suggestions and for their willingness in supplying detailed information from their personal knowledge and records. Dr. Edward B. Mathews, Director, and Mr. Charles Berry, Geologist, the Maryland Department of Geology, Mines and Water Resources; Mr. Henry C. Barksdale, Hydraulic Engineer, the United States Geologic Survey; Mr. Joseph T. Strohmeyer, Engineer, the Baltimore City Bureau of Water Supply; and Messrs. Robert R. Bennett and R. R. Meyer, who are continuing the study of ground water problems in the area.

A special acknowledgement and expression of appreciation is made to the Bethlehem Steel Company for its important contribution in initiating and carrying out, on its own responsibility, a great deal of the most valuable research and field work. Mr. L. F. Coffin, and Mr. William P. Hill were instrumental in this work, and Mr. Norman M. Shannahan furnished a great deal of valuable information.

And finally, a special debt of gratitude and appreciation is acknowledged to you for the encouragement, the advice, and the assistance, without which the preparation of this report would have been impossible.

Very respectfully submitted,

John C. Geyer

JOHN C. GEYER

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GROUND WATER IN THE
BALTIMORE INDUSTRIAL AREA

SECTION I

This report has been designed to contribute to the detailed studies and continuing effort now under way to solve the complex problems connected with the utilization of the ground water resources in the Baltimore Industrial Area.

A nontechnical survey of the current situation is presented in this introductory section for those interested only in the general nature and magnitude of ground water problems in the area. It is hoped that the detailed treatment of the subject in the body of the report will help the industries understand and solve their problems and will encourage better record keeping and more advanced conservation measures.

During the course of the studies on which the present paper is based there was initiated, primarily through the interest and influence of Dr. Abel Wolman, Professor of Sanitary Engineering at The Johns Hopkins University, and through the interest of the United States Geological Survey, a comprehensive study of the ground water problems in the Baltimore area. For this purpose the Honorable Herbert R. O'Conor, Governor of Maryland, approved the appropriation of a sum of $5000 which was matched by the United States Geological Survey. It was proposed that the total of $10,000 be spent within the fiscal year 1942-1943, and it was understood that the program should be continued for some three to five years or more in order that sufficient time might be had to gather adequate records and to carry on the necessary studies. An attempt has been made to organize and summarize existing information here so that it may be used with less expenditure of time and effort in carrying forward this new study.

During the course of the research the need for a single comprehensive list of all wells in the area became apparent. Mr. Henry C. Barksdale, United States Geological Survey states: 1/

> "Any detailed investigation in the Baltimore Area should include the location and examination, if possible, of every well in the area whether it is in use or not in order that adequate and complete plans for the control of the contamination by salt may be made."

1/ Henry C. Barksdale "Ground Water Conditions in the Vicinity of Baltimore, Maryland, with Especial Reference to the Contamination of Wells by Salt Water." Confidential Report to the U. S. Department of Interior, Geological Survey, dated July 23, 1942.

Because of this critical need for a single listing of all known wells, considerable time was spent assembling the existing data in tabular form. The various records and publications of the Maryland Geological Survey provide the major source of information for data on the older wells. Although all known sources of recorded information have been exhausted and all known or probable industrial users contacted, it is not believed that the list is complete. A personal canvass of present and former owners of all property in the area would very likely result in the discovery of the existence of unrecorded wells. The list, which presents data on about 1100 wells, should nevertheless be found a valuable reference in all further work.

History of Ground Water Development

Ground water is water contained in the zone of saturated voids in the rocks of the earth's crust and in the saturated mantel rock and soil. Since prehistoric times men have dug, bored and tunneled into the zone of saturation to capture ground water. During the thousands of years since the original shallow wells were scooped in moist places, the art of location and construction of wells has developed into a highly technical science. In 1930 some 6500 communities with about 20,000,000 inhabitants were supplied with two billion gallons daily of water from wells and many millions more living on isolated farms depended on well water. In 1929 over 2,100,000 acres were irrigated by water taken from wells. 2/ Industries are large users of ground water in areas where supplies are abundant. In Baltimore and along both sides of the Patapsco River, industries withdraw an estimated maximum of about 40 million gallons daily from wells. This amount equals approximately one-third of the total quantity of water normally supplied Baltimore City from its public water works system which cost around $90,000,000.

The first wells in Baltimore were sunk by the earliest settlers and penetrated only small distances to reach the abundant supplies in the basal gravels that overlie the crystalline rock in the area. Well drilling has continued more or less regularly with the growth of the City and its industrial expansion. Darton reported 201 deep wells in the Baltimore area in 1896. 3/

Since that time about 1000 artesian wells have been drilled, of which 150 or more are still in use. The principal industries that use ground water are listed in Table I and their general location is shown on the map, Figure 1.

2/ O.E. Meinzer "Ground Water in the United States, A Summary." U.S. Geological Survey Water Supply Paper 836-D. 1939.

3/ N. H. Darton "Artesian Well Prospects in the Atlantic Coastal Plain Region." U. S. Geological Survey Bulletin No. 138. 1896.

TABLE I

PRINCIPAL INDUSTRIES THAT USE GROUND WATER

Key to accompanying Map Figure 1

Map No.		Active Wells
1.	Eastern Rolling Mills Co.	6
2.	Monarch Rubber Co.	1
3.	Pennsylvania Water and Power	1
4.	Schluderberg-Kurdle Packing Co.	3
5.	Frankfort Distilling Co., Highlandtown	2
6.	Crown Cork & Seal Co.	3
7.	National Brewing Co.	3
8.	Baugh Chemical Co.	2
9.	American Radiator & Standard Sanitary Corp.	1
10.	Camp Holabird	3
11.	Baltimore Pure Rye Distillery	2
12.	Frankfort Distilling Co., Dundalk	1
13.	Federal Yeast Co.	3
14.	Reid-Avery Co.	1
15.	Western Electric Co.	2
16.	Chemical & Pigment Co.	4
17.	Consolidated Gas & Electric Co.	1
18.	Baltimore Transit Co.	1
19.	Bethlehem Steel Co., Wire Mill	8
20.	Bethlehem Steel Co., Sparrows Point	59
21.	Carr-Lowry Glass Co.	2
22.	Consolidated Gas & Electric Co.	2
23.	The Chesapeake Paper Board Co.	4
24.	Proctor Gamble Co.	1
25.	The Maryland Dry Dock Co.	2
26.	The Arundel Sand & Gravel Co.	1
27.	The Atlantic Terminal Co.	1
28.	Royster Guano Co.	1
29.	Continontal Oil Co.	3
30.	Brooklyn Chemical Co.	1
31.	Pan American Refining Co.	1
32.	U. S. Indsutrial Chemical Co.	3
33.	U. S. Industrial Chemical Co., Alcohol Plant.	6
34.	Standard Wholesale Phosphate Co.	4
35.	Chas. F. Walton Co.	4
36.	Armour Fertilizer Co.	1
37.	U. S. Coast Guard	1
38.	Davison Chemical Co.	3
39.	Baltimore Transit Co., Bay Shore.	3
40.	Fort Howard	2
	Total	153

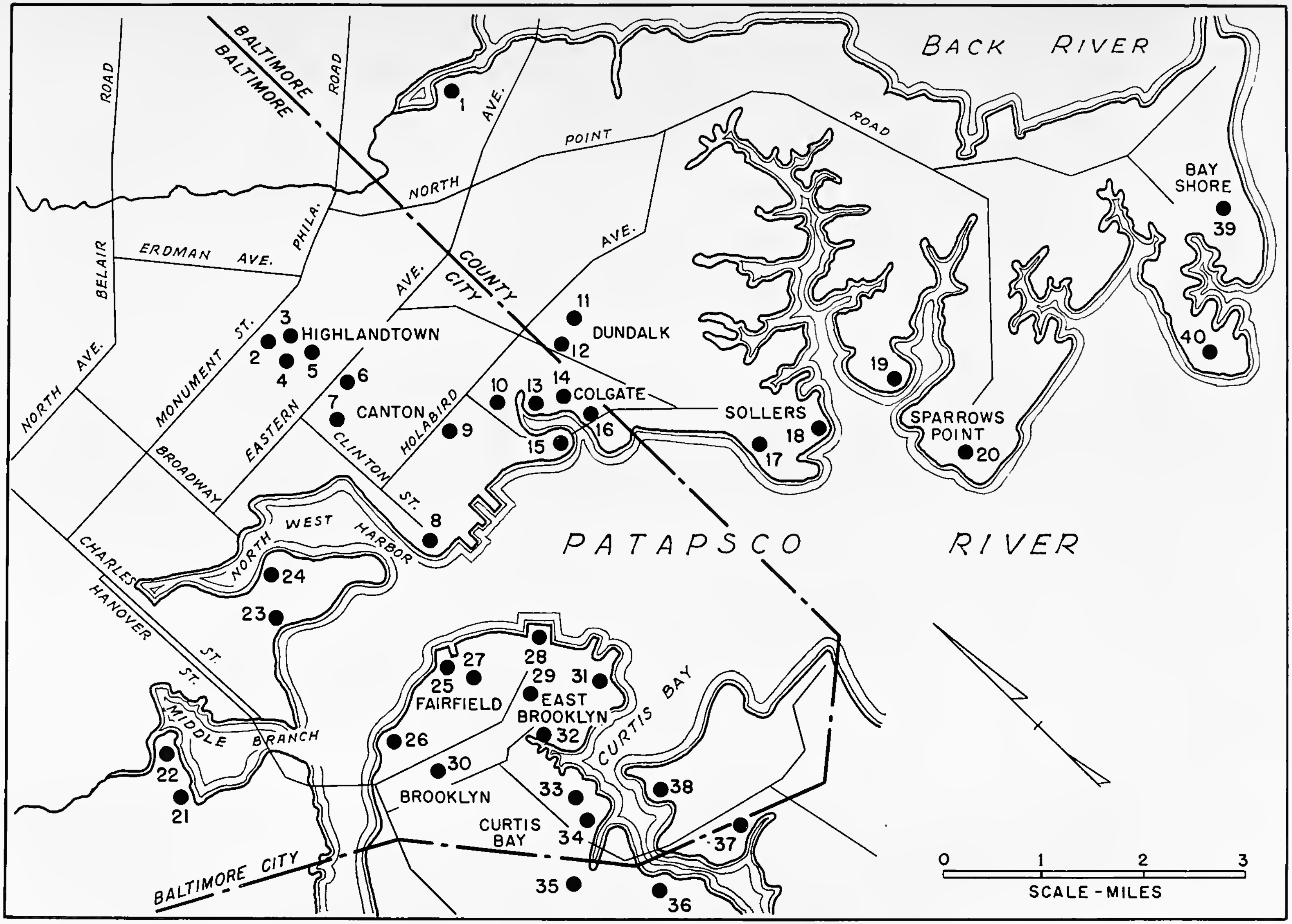

Fig. 1. Map of Baltimore Area showing the Location of Principal Ground Water Using Industries.

Geology and Hydrology

The area concerned in the present study is part of the Coastal Plain which stretches from Long Island southeast along the Atlantic and Gulf Coasts into Mexico. In the eastern United States this plain is bounded by the Atlantic Ocean and the Piedmont Plateau. In the Baltimore area abundant artesian supplies are obtained from the lower cretaceous sands and gravels which lie between beds of unconsolidated clay. A generalized cross-section of the geological structure is shown in Figure 2.

The hydrologic conditions to which these supplies owe their existence are briefly described below. Rainwater that enters the ground, percolates down to the zone of saturation to become part of the ground water body and then moves away laterally under the force of gravity which tends continually to produce a level water table. Movement underground is in many ways similar to flow on the surface. The great difference is in the velocity of motion. In medium sand and sandy gravel with a water table slope of one foot per hundred the effective velocity is in the range of one to six feet per day.

If the water moves into sand or gravel beds that dip beneath impervious clay formations the ground water becomes confined and moves somewhat as water in a pipe. The pressure in the confined conduit is controlled by the ground water level above the entrance of the channel and not by the elevation of the free water table directly above the conduit. Water will rise in a well penetrating the confined aquifer to a level determined by the elevation of the ground water surface at the distant intake. Frequently the pressure in confined beds is sufficient to cause water to flow from a well. In common terminology only flowing wells are considered artesian. Scientifically, however, an artesian well is defined as any well which taps a confined bed and in which water rises above the general level of the free water table in the area. 4/ This definition is illogical because an artesian well can no longer be considered artesian if pumping reduces the level below that of the free water table. Therefore, in all following discussion any well that taps a confined aquifer is called an artesian well.

In the Baltimore area the intakes of artesian formations are the narrow and irregular outcrops of the pervious sands and gravels of the coastal plains formations. These outcrops appear in the strips that roughly parallel the Fall Line which marks the contact between the Coastal Plain and the Piedmont Plateau. The Fall Line passes from northeast to southwest through the geographical center of Baltimore City. Most of the ground water withdrawn in Canton, Dundalk and Sparrows Point

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4/ C. H. Tolman "Ground Water". McGraw-Hill Book Company, Inc., New York, 1937. p. 56.

is probably derived from rain that falls on the ground north and west of the Philadelphia Road.

Present Ground Water Difficulties

There are five outstanding difficulties that accompany the use of ground water in the Baltimore area. These are, in order of importance: (1) salt water contamination; (2) acid contamination; (3) drop in static levels; (4) decline in discharge, and (5) loss of wells due to collapse of the well screens and casings or of the ground outside of the screens. The body of this paper is concerned primarily with the cause, the diagnosis and the cure of these difficulties.

Salt Water Contamination.

There are two types of salt water contamination. The first is entrance of salty Patapsco River water directly into the artesian aquifers through their outcrops in the upper tidal basins. The second is leakage of salty water from shallow formations down abandoned or faulty wells into the fresh water aquifers.

The area of widespread contamination around the upper harbor seems to have been caused by the entrance of salt water through outcrops in the river. Only a few wells are still in operation in this area. All are salty. Wells at the Chesapeake Paperboard Company and at the Proctor and Gamble Company on Locust Point, yield water containing 3000 parts per million (ppm) chlorides as compared with the natural chloride content in fresh aquifers of eight to twelve ppm. Patapsco River water contains about 3000 ppm chlorides at the surface, and 7000 ppm at the bottom. Farther east at the Baugh Chemical Company, Lazaretto Point, chlorides are only 500 ppm.

Wells affected by direct contamination from the river will probably never again produce fresh water and furthermore, measures may have to be taken to prevent, if possible, the movement of salt water down the dip into fresh water areas. There is no conclusive evidence that the area of general contamination is moving southeastward at a noticeable rate. Wells in Canton and on Locust Point have been salty for many years, while in the Colgate and Brooklyn-Fairfield areas wells unaffected by leakage have shown no increase in salt.

Leakage down faulty wells is the most serious difficulty in the area. The abandonment of shallow wells as salty water appeared has permitted the re-establishment of pressures in the upper aquifers, while the shifting of draft to deeper wells has reduced the pressure in the lower formations. Thus when the deep wells are pumped there is often a difference of 100 to 200 feet pressure head between the upper and the lower strata. Under this pressure salt water is forced down the operating wells when casings are perforated by corrosion or when external casing seals are broken. There is evidence of leakage

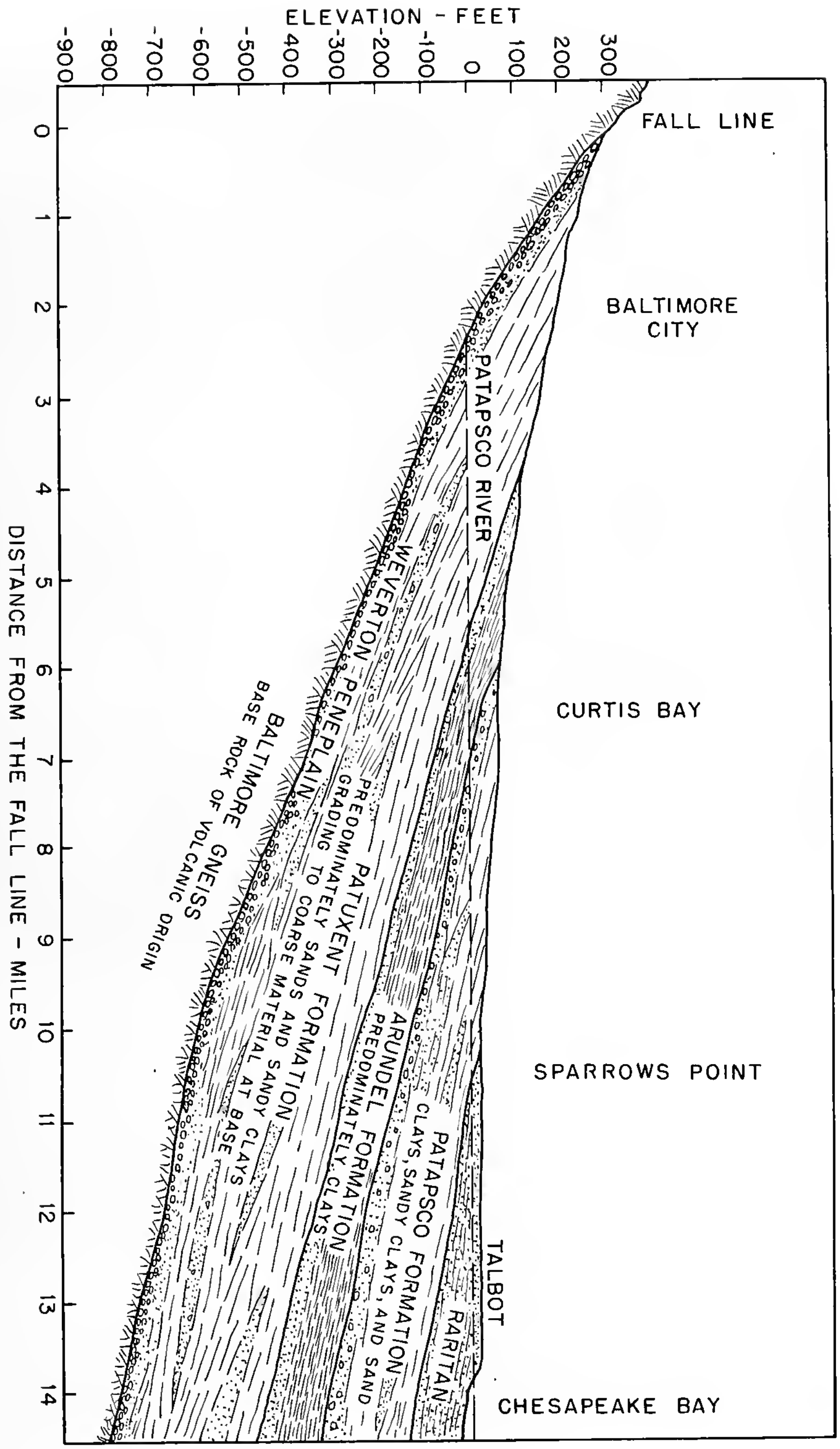

Fig. 2. Simplified Cross-Section of the Coastal Plains Formations in the Baltimore Area.

in every large group of wells in the area. A number of the fifty-one active wells at the Bethlehem Steel Company's plant show evidence of salt contamination. All the wells at the Continental Oil Company plant and three out of five of the U. S. Industrial Chemical Company's wells at the Curtis Bay plant are contaminated by vertical leakage.

Salt contamination is generally worse where abandoned wells are most numerous for many of these were left unsealed and have become permanent sources of leakage.

Experience indicates that the average useful life of wells in the area is not more than 20 years and some wells are abandoned after only four or five years of service. If these abandoned wells are not tightly sealed with cement the leakage down them will seriously impair the quality of water in nearby wells. Unless the leakage down both active and abandoned wells can be controlled there is danger that the artesian waters in the area will become unusable.

Other possible causes of salt water contamination not discussed above because they are not believed to be important are slow seepage downward through the confining beds as the pressure is reduced in the lower aquifers, and a gradual movement of salty water back up the dip from an unknown distance to the southeast where salt has not been flushed from the artesian beds.

Acid Contamination.

There is an area of fairly widespread acid contamination in and around Canton. The soil in this area has for years been notoriously acid from leakage or discharge of acid waters from metal, oil and fertilizer industries. Darton reported in 1896 that the soil in the Canton area was deeply saturated with acid and that there was probably some acid contamination from the surface in the well at the old copper works at Clinton and Conkling Streets. The area along Holabird Avenue from Highland Street eastward has been a dumping ground for slag from the old Baltimore Copper Works for a hundred years or more. Natural oxidation of the sulphur in this slag produces a great deal of the acid.

In 1930 the Bureau of Water Supply of Baltimore City undertook the construction of a 36-inch cast iron main along Holabird from Highland Street to Broening Highway. Experience in the area indicated a maximum life of five years for cast iron pipe. Tests showed one per cent free sulfuric acid in the soil. The steps taken to prevent rapid destruction of this water main illustrate the heroic measures that have to be employed to protect underground pipe in the area. The main was first painted with asphalt containing one per cent oleic acid, then wrapped in burlap dipped in the asphalt paint and finally incased in four inches of a 1-2-4 mix of concrete to which had been added 25 per cent hydrated lime by volume. 5/

5/ "Annual Report of the Department of Public Works to the Mayor and City Council of Baltimore." 1930, pp. 47 and 48.

The Crown Cork and Seal Company is the only industry that continues to use ground water in the badly affected area. One well at the Highlandtown plant yields water with a pH of 3.3. The equipment in this well is removed every year or so for major repairs.

In the Brooklyn Curtis Bay areas local acid contaminated by leakage down faulty wells is indicated in the groups at the U. S. Industrial Alcohol Company, the Davison Chemical Company, and the Standard Wholesale Phosphate and Acid Company.

Fall in Static Levels.

Ground water withdrawals had evidently had little influence on static levels until after 1900. At that time water still flowed by artesian pressure from wells drilled near the lower Patapsco River. Since then a gradual decline in static levels has occurred. By 1930 levels throughout the area had fallen to about 50 feet below the surface. Reduced consumption during the industrial depression retarded the rate of exhaustion of supplies during the early 1930's but with the renewal of normal industrial activity around 1937 the water levels declined rapidly and chlorides appeared in intolerable amounts in wells that formerly produced excellent water. In 1940-1941 static levels fell to 200 feet below the surface in places and pumping costs increased accordingly.

Reduction in Yield.

Reduction in the discharge of many wells accompanied the decline in static level. However, this has nowehere been considered as serious as the deterioration in quality. Well drilling is continuing at present in order to obtain the increased quantities needed to meet the war time demands, or to make up losses caused by the failure and abandonment of wells.

Structural Failure.

A great many wells in the area have been lost through collapse of the well screens, perforation of the casings or other equipment, or through a structural failure of the surrounding aquifer accompanied by a rapid inflow of sand. These difficulties, as well as local leakage of salt and acid water, can be corrected by the use of cement grout to seal wells. The details of remedial measures are described in Section V.

Economic Values

A comparison of cost of well water with the cost of replacing supplies by Baltimore City water shows that complete loss of the ground water resources in the area would represent a loss to the City of Baltimore, its Industries and people of $1,000,000 annually.

The total capital investment in the 150 large active wells at an estimated average cost per well of $15,000 is $2,225,000. If interest is assumed at four per cent and depreciation at five per cent, the annual fixed charges are $203,000. No accurate figure has been obtained on maintenance, but since well equipment must be removed for repair fairly frequently, the average maintenance expense probably approaches $1000 per year per well. For all wells this would amount to $150,000 annually. Pumping lifts in the area average at least 150 feet. At a power rate of one cent per K.W.H. the total annual pumping charge for 40 million gallons daily at 70 per cent efficiency is:

$$\frac{40,000,000 \times 8.33 \times 365 \times 150}{2,660,000 \times 0.7} \times 0.01 = \$98,000.$$

The total annual expense for well water used by Baltimore industries is therefore of the order of $451,000. Or the cost per 1000 gallons is:

$$\frac{451,000}{40,000 \times 565} = 3.08¢ \text{ per 1000 gallons.}$$

Data on the cost of Baltimore City water are presented in Tables II and III. Since the industries are all in the large consumer class, i.e., they would require meters at least three inches or larger, it may be seen from figures in Column 8, Table II that the cost of City water to replace well water will average about 11 cents per 1000 gallons. The total annual cost for 40 million gallons daily of City water would therefore be:

$$110 \times 40 \times 365 = \$1,600,000$$

The annual net financial loss to Baltimore should all well water have to be replaced with City water is:

$$(1,600,000 - 450,000) = \$1,150,000$$

or in round figures $1,000,000 per year. Capitalized at four per cent interest this represents a net loss of $25,000,000.

This figure probably represents the maximum possible loss if all wells were to be abandoned. Although it is unlikely that all wells will have to be abandoned, there certainly are financial losses of considerable magnitude which result from the abandonment of wells and from the increase in plant operating costs caused by salt water contamination and other difficulties.

There can be little doubt that it will be economical for the ground water using industries in the Baltimore area to expend considerable time and money in order to conserve the existing ground water supplies. This is particularly true at the present time when the City of Baltimore is having to furnish water at war time consumption rates

TABLE II

Water Consumption Registered by All Meters in Baltimore City During the Year 1929 and Revenue Therefrom 6/

Size of Meter Inches	Annual Consumption in 1,000 cu. ft.	Annual Revenue	No. of Accounts	General Revenue per Account	Annual Consumption per account 1,000 cu. ft.	Revenue per 1,000 cu. ft.	Revenue per 1,000 gals.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	86,486.0	$105,887.05	1274	$ 83.08	67.8	$1.226	16.40¢
$1\frac{1}{2}$	37,343.3	71,550.96	494	144.84	176.8	0.819	10.93
2	158,394.5	149,315.88	436	342.00	363.3	0.943	12.60
3	274,523.2	224,372.40	264	849.90	1,039.9	0.817	10.91
4	417,064.6	321,915.94	149	2,160.51	2,799.1	0.772	10.30
6	251,731.3	202,448.48	53	3,819.78	4,749.6	0.804	10.73
8	26,983.3	22,389.36	8	2,798.67	3,373.3	0.830	11.10
10	1,044.1	1,030.93	1	1,030.93	1,044.1	0.987	13.20
12	46,195.6	34,856.71	3	10,285.57	15,398.5	0.667	8.91
Special	126,044.9	28,406.65	264	107.60	477.4	0.225	3.00
Elevator	9,551.6	24,293.25	44	552.11	217.1	2.54	34.00
Total	1,485,362.4	1,186,467.61	2990				
Weighted Average				$ 396.81	496.8	$0.800	10.70¢
Weighted Average excluding Special & Elevator				422.73	503.3	0.840	11.20¢

6/ Data Columns (1) to (6), inclusive from "Report on Future Sources of Water Supply", J. H. Gregory, G. J. Requardt, and Abel Wolman, December 19, 1934, page 67.

TABLE III

Cost of Water Supply Service per Million Gallons 7/

YEAR	Operating Collect-ing	Purif.	Pump.	Dist.	Costs Total Operation	Fixed Interest	Charges Sinking Fund	Total Cost Per Million Gallons
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1932	$1.656	$6.160	$11.650	$26.041	$45.507	$42.173	$10.200	$97.880
1933	1.125	5.578	10.402	17.694	34.799	43.767	18.030	96.596
1934	1.350	5.068	9.726	18.034	54.228	42.671	17.235	94.134
1935	1.636	4.824	9.590	16.541	32.591	39.888	17.507	89.986
1936	1.360	4.567	8.871	19.204	34.002	35.674	16.310	85.986
1937	2.080	4.306	8.901	19.376	35.163	35.787	17.111	83.061
1938	2.118	4.917	9.159	21.711	37.905	38.120	19.808	95.833
1939	2.232	4.723	8.756	19.319	35.030	36.072	19.011	90.113
1940	2.190	4.797	8.473	19.656	35.116	35.092	18.588	83.796

7/ Data from the Annual Report of the Department of Public Works, Baltimore, Maryland. 1940, p. 169.

considerably in excess of the safe dry year capacity of its sources. Furthermore, the cost of developing new increments to the City's supply is becoming increasingly expensive. A capital expenditure of about $10,000,000 would be required to add 40 million gallons daily safe yield to the City's source of supply. It is believed that conservation of existing supplies in areas where the artesian waters are still fresh will not be particularly difficult if new wells are properly constructed and old ones are completely sealed when they are abandoned.

Conservation by Proper Construction and Sealing

The salt and acid contamination difficulties can be corrected by the proper use of cement grout for the construction, repair and sealing of wells. No need is more urgent than that for the adoption of proper grouting techniques. This is considered so important that Section V, which deals exclusively with grouting, has been prepared to furnish well owners details concerning grouting methods.

The objective of all grouting operations is to prevent vertical leakage either inside or outside the casing between the aquifers penetrated by a well. When grout is used in the construction of a new well to obtain a cement wall two inches or more in thickness outside the whole length of the casing, a well is obtained that should be as permanent as such structures can be made.

The development of sound techniques for the use of cement for water wells has been slower than in the drilling of oil wells where leakage involves large financial losses and hence the art of grouting has been developed to a higher level of perfection. Many of the methods and devices used by the oil industry are described in Section V. As an example of improved testing in connection with the cementing of oil wells there has been developed an open hole logging device for measuring the actual diameter of the hole. The caliper used is shown in Figure 24, page 100, and caliper logs are shown in Figure 25, page 101. The most important use of this information is to compute the amount of grout required to fill the annular hole between the casing and the hole.

Frequently in the past well drillers have assumed that the drilled hole is the same size as the bit, and that a casing with a diameter the same as that of the bit will fit tightly. It is therefore interesting to noteon the caliper logs, Figure 25, that for very considerable portions of the depth, the hole diameter is considerably more than double the bit diameter. A packer set at the foot of the casing in the unconsolidated clays of this area, in a hole of unknown diameter, could hardly be expected to provide a permanent seal against vertical leakage.

Certain fundamental rules and principles should be followed in all grouting operations if any degree of success is to be hoped for. These are:

1. Do not guess or believe, know what is being done.

2. Use the lowest water cement ratio which will accomplish the objectives of the job. For grouting around casings in new wells not more than 5 1/2 gallons of water should be used per bag of cement.

3. Mix and place the grout in one continuous operation.

4. Always place the grout from the bottom and fill the annular space or the cavity upward.

Methods of testing to determine the underground conditions in order to plan the work are discussed later with the descriptions of techniques for the use of cement grout in the construction of new, the repair of old and the sealing of abandoned wells.

If these or other methods equally as good are used, salt contamination problems should gradually be brought under control. If they are not adopted most of the well fields in the Baltimore industrial area will sooner or later have to be abandoned as sources of fresh water.

Future Record Keeping and Studies

Record keeping of ground water quantities, qualtities and of levels must be greatly improved and detailed studies must be made as a primary part of any conservation program. These records and studies are needed: a) to anticipate and if possible control the extension of general salt water contamination, b) to determine the maximum safe yield that may be developed without lowering static levels to uneconomic depths and c) to determine the location and the cause of local leakage of salt water from shallow beds into the deep fresh water aquifers.

Record Keeping.

All the past work on ground water problems in the Baltimore industrial area has dealt mainly with generalities because of the lack of sufficient observations of scientific value. Such measurements as have been made are scattered in space and in time and frequently are inadequate or unreliable.

Future record keeping should include the following three types of measurements.

1. Continuous records of water levels in unused wells that do not leak and that penetrate the various aquifers at strategic locations. A few continuous recording water level gages have been installed in connection with the newly initiated Maryland and U. S. Geological Survey cooperative study. More are needed.

The inadequacy of water level records in the Baltimore area and in Maryland is indicated by comparison of the water level and artesian pressure measurements in the State with those of the country as a whole.

In 1939 in the United States, water level records were kept for 5,500 individual wells. About 265 wells in the country were equipped with automatic water level recorders. In Maryland in 1939 there was one observation well near Colesville in which the fluctuations of the shallow or free ground water table were measured. New Jersey had 148 observation wells, 50 of which were equipped with automatic water level recorders. 8/

2. Continuous and accurate meterage of all well water pumped: The complete lack of quantity measurements in the past has been mentioned above. Every well should be equipped with some kind of metering device, if possible either a continuous recording or a quantity integrating meter. In comparison with the $5000 to $15,000 investment in the well itself the $100 to $200 required to purchase a propeller type total quantity flow meter is a relatively insignificant cost.

3. Frequent tests of static levels and dynamic levels in operating wells. These tests are needed to supplement the records gathered at strictly observation wells and to provide the industry with first hand information concerning what is happening to its source and to its wells.

4. Frequent check on the quality of the water particularly with respect to chlorides and pH values. The latter tests provide a very sensitive test for indication of leakage down a well either inside or outside the casing. The appearance of chlorides signals the need for a thorough exploration of the condition of the well . Such periodic tests are also required for following the extension of areas of general salt water contamination.

Detailed Studies Needed.

There is probably no area in the country where the ground water problems are more complex. The aquifers from which the artesian water is drawn can be idealized as sloping sheets of sand and gravel lying between thick beds of impervious clays. The accumulating evidence, however, indicates instead that the stratigraphy is highly complex, that proximate wells to the same levels do not necessarily tap the same band of water bearing sand and gravel. It cannot be said with certainty that the upper water bearing horizons are not in places connected by natural pervious channels with the lower aquifers. With the accumulation of adequate records it will probably be possible to discover the answer to many of these questions. Detailed studies of four prinicpal types are needed.

1) A general study of well logs and of water quality and static levels to determine the distinct aquifers and the wells that are drawing upon them. Sufficient well logs for such studies are now available. Their use, however, is made difficult by the unreliable methods of sampling and the non-uniform and non-specific methods used to describe the formations penetrated. For example, it is not uncommon to encounter two

8/ "Water Levels and Artesian Pressures in 1939." U. S. Department of Interior, Geological Survey Water Supply Paper 886.

logs for wells not far apart that describe what is obviously the same thick formation as sandy clay in the one, and sand mixed with boulders in the other.

2) Study of the fluctuations of static levels in relation to the rates of pumpage and the total quantities withdrawn and in relation to all the influencing hydrological factors in order to determine the safe ground water yields from wells in the area.

3) Study of the extension of the areas of general salt water contamination and investigation of the possibilities for controlling the direction and rate of this extension by proper distribution of pumping throughout the area. The Bethlehem Steel Company pumped to waste one of its wells in the vicinity of a bad leak for several years in order to keep the chloride content down in adjacent wells. Use of the scheme on a large scale presents a possible method of preventing further extension of the salt. The pumping of large quantities of very salty water for cooling purposes in the Locust Point area may now be preventing extension of the area of general contamination around the Upper Patapsco River basin.

4) Study of leakage difficulties at the individual wells to learn exactly what is happening in order to be able to plan successful corrective measures. The practice of proceeding to pump in grout or clay before knowing the underground situation, has led to a high percentage of failures in past efforts to stop leakage. It is believed that given adequate experimentation and thought most leaks can be sealed without great cost the first attempt.

As a background for these needed studies there exists a wealth of general experience and a relatively complete set of records of well location and owners. These records are described in Section III and are summarized in Appendices I, II and III. The past studies of wells and ground water in the area are listed below to serve as a guide to existing sources of information.

Past Investigations

A brief abstract and criticism of the principal past investigations is presented here as a guide to those who are interested in referring to early reports and studies.

1. "Artesian Well Prospects in the Atlantic Coastal Plain Region" by Nelson Horatio Darton, Bulletin 138, The United States Geological Survey, 1896, 3/ is the earliest known study of ground water in the area.

3/ N. H. Darton "Artesian Well Prospects in the Atlantic Coastal Plain Region". U. S. Geological Survey Bulletin No. 138. 1896.

Well owners were visited and the available data on depths, capacities, static levels and logs for 201 wells were gathered and presented in tabular form with accompanying location map. The material is well organized and affords the principal source of information concerning the early deep wells in the area. Geologic interpretations are well presented but are limited in scope and highly generalized.

2. "Water Resources of Maryland", William Bullock Clark, Edward B. Mathews and Edward W. Berry, Maryland Geological Survey, March 1918. 9/ This excellent report is the most comprehensive and authoritative publication available on wells and ground water resources in Maryland. The paper follows the pattern used by Darton, but presents a great deal more basic data and the geologic interpretations are worked out more carefully. However, no consideration is given the hydrology and hydraulics of the artesian supplies and no attempt is made to estimate ultimate safe yields. Several locations where acid destroyed casings and contaminated the artesian supplies are referred to, but salt difficulties were evidently not serious at the time the studies were made, for salt contamination is not mentioned.

3. "Baltimore County". A report by the Maryland Geological Survey, 1929, 10/ contains a nine page sketchy and poorly presented summary of the artesian ground water situation around Baltimore. It is based primarily on information presented in the 1918 report described above but does give some additional data on the abandonment of wells.

4. "Report on the Curtis Bay Water Supply for the United States Industrial Alcohol Company". A confidential report by Doctor Joseph T. Singewald, Jr., December 8, 1920. 11/ This report presents information on many of the wells in the Curtis Bay, Fairfield area. It is the first study directly concerned with the problem of salt contamination and the data presented on chloride contents of the wells at that time are extremely valuable. Experience accumulated since the preparation of the report indicates that the conclusions presented therein as to the reasons for and manner of salt contamination are subject to question. Five drawings showing locations, well logs and cross-sections in the direction of the strike and dip accompany the report.

9/ William B. Clark, Edward B. Mathews and Edward W. Berry, "Water Resources of Maryland". Maryland Geological Survey, March 1918.

10/ "Baltimore County". Maryland Geological Survey. 1929.

11/ Joseph T. Singewald, Jr., "Report on the Curtis Bay Water Supply for the United States Industrial Alcohol Company", December 8, 1920.

5. Bethlehem Steel Company Survey and reports. 1940-1941. As a result of serious chloride difficulties the Bethlehem Steel Company, Sparrows Point, Maryland, initiated a series of studies, the result of which are contained for the most part in the correspondence between Mr. L. F. Coffin, Superintendent of the Mechanical Department, the Bethlehem Steel Company and Doctor Abel Wolman, Consulting Engineer; and between Mr. Norman M. Shannahan, President of the Shannahan Artesian Well Company, Inc., and Mr. Coffin. The studies present information on: a) a survey by Bethlehem Steel Company employees of the chlorides, yields, static levels, etc., at all the industries in the area known by them to be using ground water; b) numerous studies of the problems and difficulties within the Sparrows Point Plant, and c) the history of well drilling and static levels in the area for the past 40 years prepared by Mr. Shannahan on the basis of information in his files. A study and summary of all this information is contained in the confidential report "Bethlehem Steel Company, Sparrows Point, Maryland - Preliminary Report on Water Supply", by Abel Wolman, Consulting Engineer, March 10, 1941. 12/ The United States Geological Survey participated in these studies and a memorandum on the work and its significance, entitled "Ground Water Conditions at the Sparrows Point, Maryland plant of the Bethlehem Steel Company was prepared by Mr. Henry C. Barksdale, March 9, 1941. 13/

6. In 1942 the United States Geological Survey at the request of the War Production Board sent Mr. Henry C. Barksdale to Baltimore to study the salt contamination problems at the plant of the Davison Chemical Company. The two confidential reports prepared by Mr. Barksdale present specific data on the situation at the Davison Chemical Company and an excellent review and summary of the salt contamination problem throughout the area. These papers are entitled "Report on the Ground Water Conditions at the Curtis Bay Plant of the Davison Chemical Corporation, Baltimore, Maryland", July 30, 1942, 14/ and "Ground Water Conditions in the Vicinity of Baltimore, Maryland with Special Reference to

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12/ Abel Wolman "Bethlehem Steel Company, Sparrows Point, Maryland -- Preliminary Report on Water Supply". Confidential Report. March 10, 1941.

13/ Henry C. Barksdale "Ground Water Conditions at the Sparrows Point, Maryland Plant of the Bethlehem Steel Company". Confidential Report to the U. S. Geological Survey, Department of the Interior, March 20, 1941.

14/ Henry C. Barksdale "Report on the Ground Water Conditions at the Curtis Bay Plant of the Davison Chemical Corporation, Baltimore, Maryland". Confidential Report to the U. S. Geological Survey, Department of the Interior, July 30, 1942.

the Contamination of Wells by Salt Water", July 23, 1942. 1/

Several studies of ground water quantity and methods of treatment appear in the files of the Engineering Department of the Maryland State Department of Health. The Bureau of Water Supply, City of Baltimore, has canvassed all plants in which there existed any possibility of cross-connections between ground water supplies and the public water supply. The data collected during these studies appear in the Bureau of Water Supply's cross-connection files. And finally, there exists a fund of unpublished data in the files of the Maryland Geological Survey.

1/ Henry C. Barksdale "Ground Water Conditions in the Vicinity of Baltimore, Maryland with Special Reference to the Contamination of Wells by Salt Water". Confidential Report to the U. S. Department of Interior Geological Survey, July 23, 1942.

SECTION II

GEOLOGY AND HYDROLOGY

The general fundamentals of geology and hydrology as they apply to the Baltimore Industrial Area are outlined here in order to supply the necessary background for further discussions of ground water problems.

The part of the United States in which the area under consideration lies has a benevolent climate. The annual rainfall is well distributed throughout the year and does not often deviate widely from the average of 42 inches. Stream flows are abundant and sustained. From one-third to one-half the total annual precipitation is discharged as surface runoff, the balance returns to the atmosphere by evaporation and transpiration or finds its way to tidal waters by underground paths.

Geology

The abundant ground water supplies in the Baltimore Industrial Area are obtained from the lower Cretaceous, or Potomac beds of the unconsolidated coastal plains formations. The Potomac group is divided into three principal formations - the lowest, the Patuxent; the middle, the Arundel; and the upper, the Patapsco. These three, the Patuxent, the Arundel and the Patapsco, are of moderate age, measured in geological time. Deposition of the lower formation started some 120 million years ago and the last materials of the upper layers were settled into place about 20 million years later.

The Patuxent, the Arundel and the Patapsco consist of alternating complex gravels, sands, sandy clays and vari-colored clays, all dipping in a southeastern direction at rates of 40 to 90 feet per mile. The details of thickness, dip and character are shown in Table IV. The complexity of the variations within these formations can be visualized by considering the sequence of events that caused their deposition during the 20 million years of the early Cretaceous period.

TABLE IV

LOWER CRETACEOUS FORMATIONS

Formation	Thickness	Dip Ft. per mile Max.Avg.Min.	Lithological Character
Patapsco	200	40	Sands and variegated clays.
Arundel	100-125	50	Predominantly clays, relatively homogenous. Iron carbonate nodules, etc. Little sand and gravel.
Patuxent	150-350	90 60 50	Coarse gravel nr. base. Extensive fine sands and sandy gravels. Clays in upper portion variegated and complexly interbedded.

Prior to the movements of the earth's crust which inaugurated the deposition of the Patuxent, the ancient igneous or volcanic rocks had been leveled during the earlier Jurassic period to form what has since been called the Schooley peneplain. This plain stretched back almost horizontally for several hundred miles from a coast line which was at that time somewhere east of the present Atlantic Coast. The plain was covered with products of the decomposed and weathered rock beneath.

Warping upward of this plain to the west of the present Chesapeake Bay, initiated the era in which erosion processes moved the residual product of rock decomposition from the elevated land southeastward to the submerged portions of the plain. Fine materials were carried out into bays and estuaries, while coarse material remained in stream beds and alluvial cones or along the shore line. With a gradual submergence of the whole, the processes of sorting and deposition progressed inland, leaving the coarse materials on the uncovered rock of the Schooley peneplain near the coast and moving finer materials further on to cover earlier deposits of sand and gravel now in the deeper water. Thus the Patuxent formation consists of coarse materials unevenly distributed over a rock base and covered by complexly cross bedded, partially continuous deposits of sands, sandy clays and clay that tend towards finer materials in the upper layers. The sands and gravels at the base of the Patuxent are major ground water sources. The overlying clays confine the water in these gravels and produce widespread artesian conditions. Several minor oscillations of land level during the Patuxent have complicated the geology of this formation, but ordinarily no attempt is made to interpret these complexities or to use them as a basis for further subdivision. A major emergence of the land closed the Patuxent and was followed by a period of unknown duration.

After these intervening ages of erosion a gradual resubmergence initiated the deposition of the Arundel formation in drainage patterns cut into the earlier Patuxent. Pervious materials accumulated in stream beds and estuaries and were covered in turn by clays as the land slowly subsided. Swamps prevailed and were the habitat of dinosaurs. Pervious bands of sand and sandy gravel at the base of the Arundel seem to be limited in extent and probably represent the alluvial deposits of antecedent streams. These beds are the waterbearing materials of the Arundel. The balance of the Arundel is made up of variegated sometimes brilliantly colored clays. Emergence of the land finally closed the Arundel period and again a long era of continental erosion set in. This in turn was terminated by the submergence that initiated the Patapsco.

As with the Patuxent and Arundel, the pervious formations of the Patapsco lie near its base and grade upward into impervious clays. Repetition of this alternate raising and lowering, eroding and deposition, always with variations, has continued down through the geologic ages. The eroded Patapsco was covered by the Raritan and subsequently formations which appear at or near the surface one after another, as one proceeds southeastward toward the Atlantic Ocean.

This conception of the sequence of geologic events suggests that the waterbearing strata are not continuous sheets of uniform thickness and permeability. Instead, they probably are interconnected bands and lenses of varying thickness and grading which appear at elevations determined by their manner and place of deposition in the antecedent drainage pattern.

Ground Water Hydrology

Ground water has been defined as any water lying within the saturated zone of the earth's crust. The upper surface of the ground water body, called the water table, is the level at which water stands in shallow wells or bore holes. The various forms in which ground water occurs are defined and illustrated in Figure 3. Water in the zone of aeration above the water table is called suspended water.

Ground water hydrology deals with that portion of the rainfall which enters the ground. If the earth is dry and the rainfall light, most of the water falling on the surface is absorbed, and becomes the concern of the ground water hydrologist. On the other hand, if the ground is saturated or frozen, or consists of impermeable material, little if any of the rainwater enters. Thus the proportion of rain reaching the ground water body varies widely with season, with the soil condition and with the type of rainfall. Of the water that filters into thr ground a portion is held in the soil zone and is extracted later by plants or is evaporated at the surface. Only when the demands of the soil have been met does water move slowly down to the water table.

Ground water is considered as free water when it has a freely fluctuating water table. Free ground water moves laterally under the

effects of a sloping water table just as water flows in a sloping stream or channel. Confined ground water is water trapped in a pervious stratum beneath an impervious confining bed. Its flow is similar to that in a pipe or conduit.

Fixed ground water is water held by molecular and capillary forces in very fine-grained materials.

In the eastern United States infiltration of rainwater is the common method by which the ground water body is replenished. Occasionally seepage out of streams or ponds may add some water but since the dry weather flows of eastern streams generally increase along the water course, the seepage is normally from the ground into the stream.

In order to determine whether or not the small streams crossing the fall line northeast of Baltimore were feeding water into the outcrops of the cretaceous sands and gravels, each was gaged by the cross-section and float method at several selected points. Since the measurements were made after a protracted dry spell, no surface runoff could have been coming into the streams. No measurable decrease in flow per unit watershed area could be found except that which could readily be accounted for by evaporation from swamps. The accuracy of the measurements was poor but results seemed to be sufficiently conclusive to indicate gagings of surface streams would afford little information as to the amount of water finding its way into the coastal plain aquifers.

Under natural conditions, that is, before wells are drilled, all the water that reaches the ground water body moves slowly underground to points of discharge. Discharge may occur as flow from springs or as seepage into river beds, thus maintaining the dry weather flow of streams. Or the discharge may occur as evaporation and plant transpiration in moist or swampy areas where the water table is near the surface. Water which moved down the pervious artesian strata during past ages and flushed out the original salt water, probably escaped by almost infinitely slow seepage upward through less impervious parts of the confining beds. The millions of years that intervene since the deposition of these beds have provided sufficient time for a very slow rate of escape to accomplish the flushing.

Extraction of water from wells interferes with the natural movements of ground water and reduces the discharge at normal outlets. Only as much water can be drawn continuously from wells as can be salvaged from the natural places of escape. For every gallon of water pumped out of the ground, the flow of springs, the flow of streams, or the evaporation and transpiration must somewhere be reduced by one gallon. There is, therefore, a definite limit to the amount of ground water that can be captured by pumping from wells.

Since the ground serves as a vast water storage reservoir, it is possible to withdraw large quantities for considerable periods of time without adverse effects other than a gradual lowering of the water

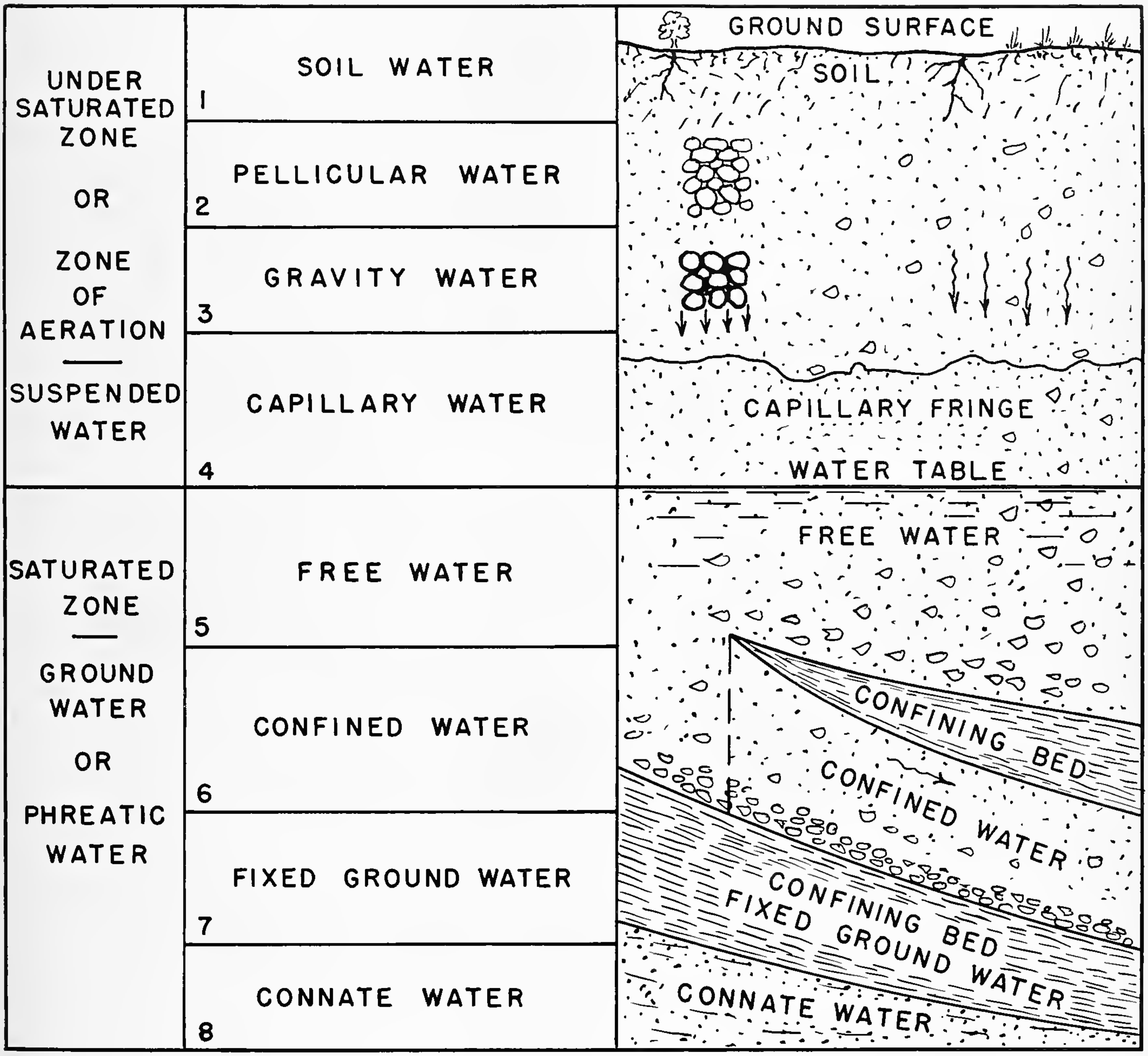


Fig. 3. Occurrence of Ground Water.

table. However, withdrawal in excess of replenishment can no more be maintained continuously than were the storage in a surface reservoir.

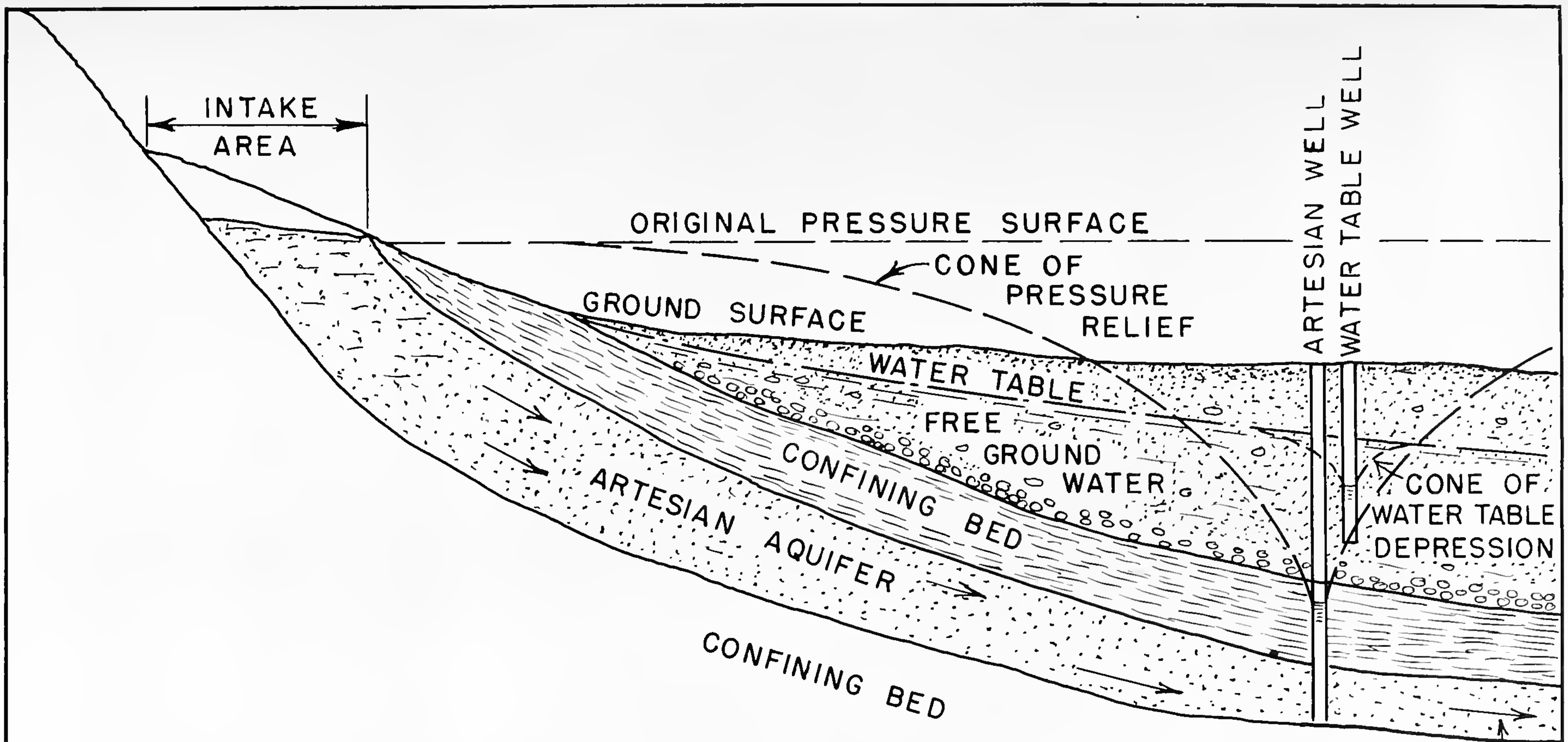
Source and Movement of Ground Water

The source and movement of free and confined ground water may be compared by referring to Figure 4.

Free ground water is fed by infiltration of rainwater from the ground surface above and moves away at very slow velocities in the direction of the water table slope to points of natural discharge. When a well that taps free ground water is pumped, the water is withdrawn from storage in the earth around the well and a cone of depression develops in the water table. If pumping continues this depression is gradually enlarged and extended until sufficient natural flow is intercepted to make up the water withdrawn. A condition of equilibrium is then reached and no further water is withdrawn from storage. The maximum yield of a free ground water well is usually equal to the amount of natural flow that can be intercepted without lowering static levels beyond economic limits. This yield can only equal the quantity of rainwater fed from the surface into the area tributary to the well.

The latter statement is equally true of artesian wells which tap confined ground water bodies. In this case, however, the hydraulic situation is different. When an artesian well is allowed to flow or is pumped a cone of pressure relief develops around the well, but the water bearing material is not emptied. Instead the water moves down the aquifer from a distant intake area. The situation is analogous to withdrawal of water from a fire hydrant in a municipal distribution system. When a hydrant is opened the water pressure drops as the water moves in the pressure pipes to the outlet, and a distant reservoir is lowered.

Since artesian systems are imperfect and elastic conduits the water that reaches an artesian well may be derived from a variety of sources. A complete list of the possible source of artesian flow includes the following: (1) Flow from the natural intake area at the outcrop of the aquifer. Generally the principal source. (2) Compression of the aquifer as the pressure is relieved. (3) Leakage downward through confining beds as pressures are reduced in the lower formations. (4) Consolidation of the confining beds because water can be squeezed more readily from them. (5) Return flow from natural discharge area, which in some cases may be the ocean. And (6) Leakage down abandoned wells or perhaps down the well from which the water is drawn. That some of these sources are temporary and may furnish water of very inferior quality is evident. Their existence greatly complicates any attempt to evaluate the safe continuous yield of an artesian formation.



POSSIBLE SOURCES OF ARTESIAN WATER

1. DISTANT INTAKE AREA
2. COMPRESSION OF AQUIFER
3. LEAKAGE THROUGH CONFINING BEDS
4. CONSOLIDATION OF CONFINING BEDS
5. RETURN FLOW FROM NATURAL DISCHARGE AREA
6. LEAKAGE DOWN ABANDONED WELLS

Fig. 4. Hydrology and Hydraulics of Artesian Ground Waters.

SECTION III

WELL RECORDS AND STUDIES

The well records and logs which appear in the appendices to this report are briefly discussed here. The difficulties encountered in attempts to use these records for scientific study are described and the data on static levels are assembled to show the continuous decline in water levels that has been taking place in the Baltimore area during the last 40 years.

List of Wells in the Baltimore Area

When the present work on the ground water problems in the Baltimore Industrial area was undertaken an attempt was made to select the information desired for study directly from the existing well records. As the work proceeded this method of attack became so involved that it was finally decided all the available data should be brought together, organized and cross-referenced. This was accomplished by preparing a single tabular summary of the data on about 1100 wells in the area. The summary appears in Appendix I and is called the List of Wells in the Baltimore area. The specific reasons for preparing the list are as follows: One, the available information on wells in the Baltimore area appears in a variety of publications, reports, letters, blueprints, maps, card index systems and files. Two, there were many discrepancies and a great deal of overlapping which could be discovered and untangled only by bringing the data together. Three, since the location, depths, and other data on all old abandoned wells is important in examining the possible sources of salt and acid contamination, there are no wells which can be eliminated entirely from consideration in the continuing studies. The preparation of the list with the compositing of information on each well consumed a large proportion of the time given to this study.

The various index and location schemes used by the Maryland Geological Survey are explained in Appendix I. Since these are related to old maps and are difficult to work with for a variety of reasons, a new location system based on mile squares measured from the Washington Monument has been adopted. The new location numbers have been worked out in sufficient detail to provide reasonably easy access to available data. The List is cross-referenced in Appendix II in order that wells may be referred to either by owner or by location.

As work continues in the area all the information called for in the List of Wells should be conscientiously entered as it becomes available. If this is done the list will multiply in value and the errors which it now contains will gradually disappear. The list was prepared because the available information is extremely difficult

to use in the overlapping and disorganized condition in which it is to be found in the existing well records. Maintenance of the list will reduce this difficulty in the future.

Well Logs

Ninety-four well logs were located during the course of the work and are presented in Appendix III. The list of logs is complete insofar as the public records are concerned. There are no doubt many additional logs in the files of the various well drilling companies. One man's full time for at least a year would be required to go into the records of the drilling companies in order to dig out all the valuable information buried there. For the most part, well logs have been made available to the public through the well owners. It is believed that the list of logs in Appendix III is fairly complete as far as owners' records are concerned, and that the drillers' files are the only unexplored abundant sources.

The logs are arranged alphabetically according to owners and are distinguished by cross referencing each log to the sheet and line number in the List of Wells in the Baltimore Area. These logs were strip plotted to a vertical scale of 1" = 100' for transfer on to profiles taken along the strike and dip. The preparation of profiles was undertaken, but the use of logs alone did not seem to provide sufficient information to say with certainty which wells tapped the same equifers. The work was therefore left unfinished until enough static level data could be obtained to carry on correlations between the rise and fall of the water surface in observation wells and the starting and stopping of pumping in other wells. The latter information should provide conclusive evidence of interconnection of aquifers.

The Maryland Geological Survey has prepared a map showing contours on the crystalline basement rock throughout Baltimore. */ This map shows the presence of a pre-Cretaceous valley running south beneath Highlandtown which is believed to have considerable effect upon movement of underground water in that area. Preparation of accurate maps of the coastal plain rock floor for the area outside Baltimore City would be a worthy undertaking. Seismic, torsion balance, magnitometer or other methods of geophysical investigation provide admirable means for determining the depth of the rock floor. In the past the surface of the rock floor has been assumed to be

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*/ Map of Baltimore City showing the Configuration of the Underlying Rock Floor. Prepared by the Maryland Geological Survey under the direction of Dr. E. B. Mathews from information secured by C. W. A. workers. 1935.

a uniformly dipping plane but whenever concrete evidence is obtained, doubt is thrown on this assumption. The marked irregularities shown in the rock floor contour map of Baltimore is an example of this. The logs for the Bethlehem Steel Company's deep wells show that the rock floor beneath Sparrows Point is generally level with a mound in the vicinity of the Coke Ovens under the southwest corner of the Point and a depression under the Hot Strip Mill in the northwest corner. Construction of an accurate base rock map would assist greatly in efforts to interpret plotted well logs.

Studies of Well Records

Detailed studies of the stratigraphy and underground hydraulic conditions were planned in order that the distinct artesian systems in the area could be determined. Using this information it was hoped that the significance of the decline in static levels and the increase in chlorides and other undesirable mineral constituents could be interpreted. This objective was not fully attained for the following reasons: (1), the amount of work required was beyond that possible within the available time; (2), the records of amounts of water used and of static levels were not sufficiently accurate for conclusive work; (3), the fairly conclusive evidence that the major problems result from leakage down improperly constructed or down abandoned and unsealed wells, directed the study toward investigation of these difficulties and the methods available for correcting them; and (4), in connection with the recently initiated cooperative study accurate measurements will be made and the problem of stratigraphy, hydrology, and hydraulics studied in detail. Mr. Bennett and Mr. Meyer are working full time on this problem and have at their disposal considerable resources, yet it will very likely take them three to five years to obtain the necessary information and to make the studies required to clarify many of the questions involved. A number of ground water producing areas where the situation is no more complex have been under continuous study for many years.

In the following pages the fall in static levels and the chloride difficulties are discussed only in the detail which seems justified by the data available at present.

Static Levels

Information on static levels and yields of wells in the Baltimore area is scattered and unreliable. Frequently the static level is determined at the time a well is drilled and is given no more attention until difficulty is experienced. If the static levels drop below the pump intake or the well delivery falls off rapidly for some other reason, an investigation of the trouble is sometimes made and this may include observation of the static level. This situation could be easily remedied because many of the modern turbine pumped wells in the area are equipped with static level gages. Data are

needed which give some idea of the seasonal rise and fall in levels. The measurements should be made weekly or monthly at wells scattered throughout the area. All measurements should be made simultaneously at a time when the largest number of wells have been shut down for the longest period. Early Monday morning appears to be the most desirable time.

The scarcity of accurate records of quantities of well water used has been discussed on page 14. The magnitude of yields stated in the literature vary from guesses to approximate field measurements. The most accurate of these measurements usually apply to test conditions rather than ordinary continuous operation. There are generally no records of the time wells are in and out of operation. The latter could be remedied by furnishing the operating men record sheets and requiring that they set down the times when the well is turned on and off.

In order to form a general picture of the past history of static levels in the Baltimore Industrial area, the preliminary studies of well logs were used to correlate the aquifers. Static level data which were sufficiently complete to be usuable were then taken from the list of wells and used for the following interpretations. The very general nature of these interpretations is indicated by the numerous sources of error that may be involved. These errors are due to one or more of the following things: (1), the grouping of wells according to aquifers is subject to question because of uncertainties as to the true stratigraphic situation; (2), the static levels are all more or less affected by pumping in nearby wells, e.g., in some places where wells are only a few feet apart the level in the well which is shut down for measurement may be determined primarily by the pumping level in the adjacent wells; (3), as a result of leakage outside or through the casing the static level reading may be affected by the circulation within the well: (4), all static levels have been assumed to be related to the ground surface elevation which for the wells selected varies between 10 and 20 feet above mean low water, but there is no certainty that the ground surface was the reference level, and (5), the data are only supposed to be static levels, some of them may actually be pumping levels. The data used are shown in Tables V, VI, VII, VIII and IX.

Water Bearing Horizons.

There seem to be four principal water bearing horizons in the area. Darton 3/ and the Geologists of the Maryland Geological

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3/ N. H. Darton "Artesian Well Prospects in the Atlantic Coastal Plain Region". U. S. Geological Survey Bulletin No. 138. 1896.

TABLE V

Static Levels

In the Lower Canton, Colgate Creek, Dundalk Area

For HORIZON A

Arranged Chronologically

Owner	Location	Depth	Date	Static Level *
1	2	3	4	5
Camp Holabird	Colgate Creek	275	1906	14
Northern Central R.R.	Lower Canton	296	1907	16
Baugh Chemical	Lower Canton	245	1908	18
Baugh Chemical	Lower Canton	237	1915	22
Bartlett-Hayward	Turner's Sta.	550	1915	20
Camp Holabird	Colgate Creek	257	1918	36
Federal Yeast Company	Colgate Creek	309	1921	24
Amer.Rad.Std.San.Corp.	Colgate Creek	279	1926	50
Western Electric Co.	Colgate Creek	301	1930	27
Camp Holabird	Colgate Creek	265	1930	60
Camp Holabird	Colgate Creek	257	1932	60
Federal Yeast Co.	Colgate Creek	378	1935	50
Federal Yeast Co.	Colgate Creek	378	1936	59
Frankfort Dist. Co.	Dundalk	400	1936	75
Chem. & Pigment Co.	Colgate Creek	425	1938	80
Baltimore Pure Rye Co.	Dundalk	379	1939	100
Baugh Chemical Co.	Lower Canton	245	1941	82
Amer.Rad.Std.San.Corp.	Colgate Creek	279	1941	80
Western Electric Co.	Colgate Creek	301	1941	90
Chemical & Pigment Co.	Colgate Creek	425	1941	90
Frankfort Dist. Co.	Dundalk	400	1941	98
Baltimore Pure Rye Co.	Dundalk	379	1942	124

* Static level is in feet below the ground surface. Ground Surface Elevation varies from 10 to 20 feet.

TABLE VI

Static Levels

In the Fairfield, Curtis Bay Area

For HORIZON A

Arranged Chronologically

Owner	Location	Depth	Date	Static Level
1	2	3	4	5
Martin Wagner	East Brooklyn	373	1898	+
Rasin Monumental Co.	Fairfield	350	1901	8
Union Shipbldg. Co.	Fairfield	310	1912	10
U.S. Ind. Chem. Co.	Fairfield	358	1916	37
Armour Fert. Co.	Curtis Bay	420	1918	30
Maryland Drydock Co.	Fairfield	262	1926	40
Std. Wholesale Phosphate	Curtis Bay	344	1929	61
Continental Oil Co.	Fairfield	352	1931	55
Pan.Amer.Refining Co.	East Brooklyn	400	1933	45
U.S. Ind. Chem. Co.	Fairfield	358	1935	87
U.S. Ind. Alcohol Co.	Curtis Bay	357	1935	90
Continental Oil Co.	Fairfield	345	1936	67
Continental Oil Co.	Fairfield	344	1936	88
Continental Oil Co.	Fairfield	361	1937	94
Continental Oil Co.	Fairfield	358	1937	112
U.S. Ind. Chem. Co.	Fairfield	360	1938	112
Pan.Amer.Refining Co.	East Brooklyn	396	1939	104
Maryland Drydock Co.	Fairfield	262	1941	51 ?
Std.Wholesale Phosphate	Curtis Bay	344	1941	100
Std.Wholesale Phosphate	Curtis Bay	339	1941	107

TABLE VII

Static Levels

In the Sparrows Point Area

For HORIZON A

Arranged Chronologically

Owner	Location	Depth	Date	Static Level
1	2	3	4	5
Bethlehem Steel Co.	Coke Oven	609	1917	17
Bethlehem Steel Co.	40" Mill	655	1936	70
Bethlehem Steel Co.	Tin Mill	659	1936	71
Bethlehem Steel Co.	Tin Mill	669	1936	72
Bethlehem Steel Co.	Hot Strip Mill	668	1937	103
Bethlehem Steel Co.	Hot Strip Mill	680	1937	86
Bethlehem Steel Co.	Hot Strip Mill	685	1937	104
Bethlehem Steel Co.	Mould Yard	655	1938	97
Bethlehem Steel Co.	Wire Mill	616	1942	145
Bethlehem Steel Co.	Wire Mill	610	1942	142
Bethlehem Steel Co.	Wire Mill	625	1942	153
Bethlehem Steel Co.	Wire Mill	618	1942	132
Bethlehem Steel Co.	40" Mill	655	1942	160
Bethlehem Steel Co.	Mould Yard	655	1942	128
Bethlehem Steel Co.	Tin Mill	669	1942	129
Bethlehem Steel Co.	Tin Mill	659	1942	138
Bethlehem Steel Co.	Hot Strip Mill	668	1942	144
Bethlehem Steel Co.	Hot Strip Mill	680	1942	160

TABLE VIII

Static Levels

For HORIZON B

Arranged Chronologically for Various Areas

Owner	Location	Depth	Date	Static Level
1	2	3	4	5
Booth Packing Co.	Canton	94	1884	12
U.S.Govt. Lazarette Pt.	Canton	165	1886	18
Baltimore Copper Works	Canton	214	1906	36
Standard Oil Co.	Canton	184	1908	54
Baugh Chemical Co.	Canton	171	1941	70
Continental Oil Co.	Curtis Bay-Fairfield	225	1916	30
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	212	1916	47
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	285	1917	30
U. S. Asphalt	Curtis Bay-Fairfield	300	1917	28
Davison Chemical Co.	Curtis Bay-Fairfield	323	1919	22
Davison Chemical Co.	Curtis Bay-Fairfield	306	1924	58
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	295	1935	70
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	228	1935	65
U.S. Ind. Chem. Co.	Curtis Bay-Fairfield	265	1935	69
U.S. Ind. Chem. Co.	Curtis Bay-Fairfield	258	1935	76
U.S. Ind. Chem. Co.	Curtis Bay-Fairfield	292	1935	78
U.S. Ind. Chem. Co.	Curtis Bay-Fairfield	306	1936	65
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	227	1939	76
Davison Chemical Co.	Curtis Bay-Fairfield	335	1939	89
U.S. Ind. Alcohol Co.	Curtis Bay-Fairfield	300	1940	106
Bethlehem Steel Co.	Sparrows Point	502	1909	2
Bethlehem Steel Co.	Sparrows Point	495	1909	5
Bethlehem Steel Co.	Sparrows Point	513	1909	4
Bethlehem Steel Co.	Sparrows Point	527	1917	20
Bethlehem Steel Co.	Sparrows Point	538	1932	50
Bethlehem Steel Co.	Sparrows Point	513	1937	127
Bethlehem Steel Co.	Sparrows Point	503	1941	135
Bethlehem Steel Co.	Sparrows Point	538	1942	108
Bethlehem Steel Co.	Sparrows Point	513	1942	203
Baltimore Transit Co.	Bay Shore Park	743	1907	+15
Baltimore Transit Co.	Bay Shore Park	743	1941	68

TABLE IX

Static Levels

For HORIZON C

Arranged Chronologically for Various Areas

Owner	Location	Depth	Date	Static Level
1	2	3	4	5
Chesterwood Free Exc.Grd.	Bear Creek	170	1903	+3
Baltimore Transit Co.	Bay Shore Pwr.House	224	1903	16
Bethlehem Steel Co.	Sparrows Point	303	1900	24
Bethlehem Steel Co.	Sparrows Point	301	1905	24
Bethlehem Steel Co.	Sparrows Point	286	1916	42
Bethlehem Steel Co.	Sparrows Point	332	1916	27
Bethlehem Steel Co.	Sparrows Point	279	1917	58
Bethlehem Steel Co.	Sparrows Point	309	1917	60
Bethlehem Steel Co.	Sparrows Point	288	1917	68
Bethlehem Steel Co.	Sparrows Point	291	1930	97
Bethlehem Steel Co.	Sparrows Point	336	1937	110
Bethlehem Steel Co.	Sparrows Point	330	1937	76
Bethlehem Steel Co.	Sparrows Point	335	1937	78
Bethlehem Steel Co.	Sparrows Point	300	1937	72
Bethlehem Steel Co.	Sparrows Point	295	1938	88
Bethlehem Steel Co.	Sparrows Point	369	1939	165
Bethlehem Steel Co.	Sparrows Point	320	1939	168
Bethlehem Steel Co.	Sparrows Point	330	1939	190
Bethlehem Steel Co.	Sparrows Point	317	1940	106
Bethlehem Steel Co.	Sparrows Point	302	1940	122
Bethlehem Steel Co.	Sparrows Point	264	1940	135
Bethlehem Steel Co.	Sparrows Point	303	1940	120
Bethlehem Steel Co.	Sparrows Point	279	1941	86
Bethlehem Steel Co.	Sparrows Point	302	1942	144
Bethlehem Steel Co.	Sparrows Point	336	1942	152
Bethlehem Steel Co.	Sparrows Point	330	1942	217
Bethlehem Steel Co.	Sparrows Point	335	1942	168
Bethlehem Steel Co.	Sparrows Point	300	1942	114
Bethlehem Steel Co.	Sparrows Point	295	1942	140
Baltimore Transit Co.	Bay Shore Park	402	1907	+3
Baltimore Transit Co.	Bay Shore Park	342	1916	10
Baltimore Transit Co.	Bay Shore Park	342	1940	35
Davison Chemical Co.	Curtis Bay	240	1909	8
Davison Chemical Co.	Curtis Bay	244	1938	61
Southern Products Co.	Bodkin Creek	431	1908	+4

Survey 9/ reached this conclusion which is in accord with the accepted periodicity in the geologic history of the area, and seems to be borne out by studies of well logs.

Darton's designations of A, B, C, and D are used for the four water bearing formations of the current interpretation. Horizon A lies just above the rock floor and is a major water producer throughout the area. Horizon B lies in the lower half of the Patuxent formation and is a major producer in the Fairfield-Curtis Bay area. Horizon C probably marks the change from the Patuxent to the Arundel formation. It was formerly used extensively in the Canton area and is still one of the principal producers at Sparrows Point. Horizon D was formerly used at Sparrows Point but has been almost completely abandoned now on account of salt contamination. The general levels at which these equifers occur in the various areas are shown in Table X. The range of depths shown has no relation to the thickness of the equifers but simply indicates the limiting depths of wells believed to draw from each.

Significance of Static Levels.

Interpretations of the static levels shown in Tables V, VI, VII, VIII and IX are as follows:

Horizon A. Before 1900 water was drawn from Horizon A in considerable quantities around the inner harbor and throughout the Canton area. Static levels of 40 to 50 feet below the surface in 1900 to 1905 have been reported for old wells in Canton. Up until 1936 when last measurements were reported the static level had not changed much, probably because the rate of abandonment of wells about compensated for the effect of increased draft elsewhere. Early data on the Horizon in the old parts of Baltimore are so confused and unreliable that values presented in the list of wells have not been summarized in a separate table.

Study of Tables V, VI and VII for Horizon A show that about 1900 the static level was close to the surface in all areas other than Canton and the upper harbor. By 1915 levels had fallen to 15 to 25 feet below the surface, in 1925 to 25 to 50 feet, in 1935 to 50 to 75 feet and by 1937 to 75 to 100 feet. Thus the general decline was somewhere around 25 feet per decade until 1935 when a decline of this amount took place in only two years. Prior to 1937 the static levels in the Fairfield-Curtis Bay area and the Sparrows Point area were approximately the same, while in the wells around Colgate Creek

9/ William B. Clark, Edward B. Mathews and Edward W. Berry, "Water Resources of Maryland", Maryland Geological Survey, March 1918.

TABLE X

DEPTHS TO VARIOUS WATER BEARING HORIZONS IN THE BALTIMORE AREA

	Horizon			
Area	A	B	C	D
Canton	230-300	150-200	75-100	Surface
Colgate Creek	275-400	200-250	100-150	0-50
Fairfield	275-400			
Curtis Bay	340-450	200-330	100-200	50-100
Dundalk	400-500			
Sparrows Point	600-700	500-550	280-330	150-250
Bay Shore	?	750	350-400	200-250

the water stood at a somewhat higher elevation. In 1937 the draft at the Bethlehem Steel Company increased rapidly, and by 1942 static levels in Horizon A at Sparrows Point had declined to 125 to 150 feet. During this period the levels at Sparrows Point were the lowest in the area. Since the new Back River Sewage Water Supply has been introduced the pumping has declined at Sparrows Point and water levels are rising.

The figures on Horizon A indicate that normally the entire industrial area acts as a single well field with one large depression in the piezometric surface. There have been local depressions in the general level in this field as pumping temporarily increased at one point or another, but generally speaking the static levels have fallen uniformly throughout the whole area. Thus the ground water must flow into the Horizon A depression along the Patapsco River, from all directions. Since there is still fairly heavy pumping of salty water in the upper Patapsco area and as the salt water from this area does not seem to be progressing rapidly southeastward it must be concluded that the major portion of fresh water withdrawn moves to the area from the northeast and the southwest. This, of course, would be expected on account of the fact that a very long strip of outcrop would be required to capture the amounts of water taken from the formation.

Horizon B. Levels for Horizon B show the same early decline in the Harbor - Canton area that occurred in Horizon A. Probably as late as 1910 the natural level, which must have been close to the surface, had been little affected in this aquifer except near the center of the old city. Later as drafts increased in the Fairfield-Curtis Bay area and the Sparrows Point area, levels declined at a rate of about 15 to 20 feet per decade up to 1935 when a rapid decline set in. In 1910 to 1920 the levels in this aquifer seem to have been

lowest in the Fairfield-Curtis Bay area while after 1937 they were consistently lower at Sparrows Point. The observations made by the Bethlehem Steel Company at the 743 foot Bay Shore Park well of the Baltimore Transit Company show the wide depression created in the piezometric surface. This well is three miles east of Sparrows Point, and since it is used very little, it serves admirably as an observation well outside the general area of pumping. The level in this well has fallen 83 feet in 34 years as a result of the heavy pumping at Sparrows Point and elsewhere in the area.

The extent of the area affected by pumping may be estimated from the observation of static level of 68 feet in 743 foot Bay Shore Park well. The following assumptions are made in this connection.

1. The whole of Sparrows Point functions as a single well with an estimated diameter of 2000 feet.

2. The average drawdown at Sparrows Point at the time the Bay Shore Park level was observed was 150 feet.

3. The aquifer is unlimited in extent and has a uniform thickness and permeability.

Using Darcy's law that velocity is proportional to the hydraulic gradient, the drawdown or pressure relief at various distances from the well field has been computed and appears in Table XI. Since the above assumptions are highly generalized the computed drawdowns can be considered only as giving a rough idea of the widespread influence that heavy pumping has on static levels in artesian aquifers. The derivation of the theoretical formula on which these computations are based appears in Appendix IV, page 196.

TABLE XI

Estimated Drawdown on Horizon B Around Sparrows Point

Distance from Sparrows Point		Drawdown or Pressure Relief
Miles	Feet	Feet
0	0	150
1	5,280	113
2	10,560	85
3	15,840	68
5	26,400	48
10	52,800	20
15	79,200	6
17	90,000	0

Horizon C. Around 1900 the static level in Horizon C had already been lowered to some 24 feet at Sparrows Point but the effect of withdrawals evidently was fairly local for the static level in the well at the Chesterwood Free Excursion Grounds, two miles northwest was +3 in 1903, in the Bay Shore Park Well three miles east was +3 in 1907 and in the Southern Products Company well six miles southeast was +4 in 1908. Since that time the level has declined rather erratically at about 30 feet per decade at Sparrows Point. Little water is used from this formation in other parts of the industrial area.

Further study based on more adequate information may show that the correlations and interpretations presented herein are incorrect. For example, tests now under way indicate the possibility that the deep formations at Sparrows Point may not be connected directly with the lowest formations in the Colgate Creek Area. If this is the case much further work will have to be done to determine the true stratigraphic picture and learn the location of the outcrops or the connections with upper beds which feed water into these lower formations.

It is certain, however, that static levels have declined without interruption. Furthermore, it is very probable that the whole area acts as a single field into which water is drawn from all directions, that which comes back in from the southeast originating from outcrops far up or down the fall line. Thus there must be for each general static level throughout the area a certain total amount of water that can be withdrawn continuously. If static levels are to be kept at fixed depths than the withdrawals must be fixed. At present conditions in the area are probably improving as a result of the decreased pumping at Sparrows Point. If in the future new drafts are placed on the aquifers more rapidly than old wells and their supplies are abandoned the levels will continue downward. The two alternatives are: (1), conserve the ground water by using less of it for wasteful cooling purposes; or (2), prevent the uncontrolled drilling of wells in the area. It is believed that the first step may be all that is required to maintain reasonable static levels and yet have adequate supplies for all legitimate uses in the area.

The decline in static level is, however, only part of the problem. The serious contamination with salt, acid and other undesirable mineral constituents must be remedied or most of the equifers will have to be abandoned as fresh water sources no matter what happens to the static levels.

SECTION IV

CHLORIDE PROBLEMS

The problem of chloride contamination is the most serious difficulty in the Baltimore Industrial Area. If the present rate of deterioration of ground water continues, it is probable that many of the present well fields will have to be abandoned as fresh water sources, and the supplies replaced by Baltimore City water. The common conclusion of all investigators who have studied the chloride contamination problem since 1939, is that vertical leakage down both used and abandoned wells is responsible for the increase of chlorides in all wells except those around the upper Patapsco River. This section, therefore, deals primarily with questions of well leakage. The evidence that leakage is responsible for the contamination and the methods available for determining the source, the manner and the amount of the leakage are discussed.

The first evidence of salt contamination appears in Darton's report 3/ which refers to bad water and brackish water in a few wells around the upper harbor. However, it is specifically stated that water from most wells was of fine quality. It appears that when Darton made his investigation prior to 1896, there was some chloride contamination probably due to local leakage but that most of the wells around the northwest Branch yielded fresh water. Thus the situation on the Upper Patapsco at that time was somewhat similar to that which now prevails farther to the southeast.

The Maryland Geological Survey-1918 Report "Water Resources of Maryland" mentions numerous abandonment of wells but attributes these to the rapid disintegration of casings in the acid saturated soil and to changes in the downtown section after the fire.

In 1920, problems of local salt contaimnation at the plant of the U. S. Industrial Alcohol plant in Curtis Bay had become so serious that Dr. Joseph T. Singewald was engaged to advise a solution of the problem. The numerous chloride determinations made in connection with Dr. Singewald's study indicate that the situation then was very similar to the one which exists in the area today. Many wells produced water of fine quality but others scattered among them were contaminated with chlorides.

3/ N. H. Darton "Artesian Well Prospects in the Atlantic Coastal Plain Region". U. S. Geological Survey Bulletin No. 138. 1896.

During the period since Darton's work practically all the wells he listed have been abandoned and the area in which most of these wells were drilled now produces only high chloride water. In fact some of the wells around the harbor which still remain in use, yield water with a chloride content the same as that of the water in the harbor, and are thus little more than an underground intake for pumping from the Patapsco.

The area of widespread salt contamination which has developed in old Baltimore does not seem to have spread southeastward at an appreciable rate during the last ten years. The only plausible explanations for this are the facts that the volume of water in the aquifers is so large that displacement is a very slow process and that continued pumping of salty water in the contaminated area clears the formation of salt at about the rate at which it flows in from the river. The only wells that have become salty in recent years which may indicate dangerous extension of the area of general contamination, are those of the Maryland Drydock Company at Fairfield and those of the industries in Highlandtown. Since these wells are closest to the area of widespread salt they should be tested very carefully to determine whether the increase in chlorides is due to leakage or to movement of salt water down the dip from the highly contaminated area.

There is little that can be done to improve the quality of ground water around the upper Patapsco River and possibly the only means of preventing or of decreasing the movement of salt southeast into areas that are now fresh, is continued pumping of salt water from wells in the contaminated area. Dredging probably keeps the outcrops of the aquifers in the upper harbor open to infiltration. If all dredging and all pumping could be stopped it is probable that with the reestablishment of high static levels in the ground and uninterrupted sedimentation of silt and organic matter in the harbor a blanket would soon form which would prevent further flow of salty water into the pervious beds. It is, of course, impossible to discontinue the harbor improvements.

The balance of the discussion of chloride contamination will be confined to the problems that have developed in areas where fresh water is still available. In these areas, where the largest ground water supplies have been developed, there are good possibilities for improving the situation. For the Colgate Creek, Dundalk, Sparrows Point, Fairfield and Curtis Bay areas, there is abundant evidence that all of the contamination is due to vertical leakage. Methods used for diagnosis and correction of leakage difficulties are described below.

Leakage

Leakage down used and abandoned wells is indicated as the source of salt contamination both by indirect reasoning from a knowledge of the drilling methods used and experience with these methods elsewhere, and by direct analysis of the accumulated tests and experience in the area.

Reasons for Expecting Wells to Leak.

The reasons why it might be expected that vertical leakage would occur either inside or outside the casing of wells drilled in this area are as follows: (1), the drilling methods used produce a hole larger than the casing but of unknown size, and means to prevent outside leakage are usually applied only at the extreme lower end of the casing; (2), the development of uncemented wells is known to cause erosion and opening of channels along the casing unless considerable care is exercised; (3), the use of gravel conductors greatly increases the opportunities for vertical leakage; (4), the high rates of pumping create great head differences between the upper contaminated formations and the deeper fresh water aquifers; (5), the highly corrosive shallow waters are certain to attack the casing and produce perforations; and (6), the common methods used to prevent leakage along well casings would not be tolerated in the laying of pipes through earth dams because of certainty of failure.

1. Drilling. Both churn drilling and rotary drilling have been used to bore wells in the area under consideration. The rotary method, however, is now used almost exclusively by all the large well drilling companies. When drilling in the unconsolidated sands and clays of the coastal plains formations, either method will produce a hole considerably larger than the diameter of the bit. So far as is known, no effort has ever been made to caliper log a water well in this area, but the experience with oil wells where diameters of two to three times the bit diameter have been observed in formations that are tougher than the sands and clays here, indicates that oversize wells are to be expected. Oil well caliper logs are mentioned on pages 13 and 99 and a caliper and logs are shown in Figure 24 and 25, pages 100 and 101. Experience with caliper logging in the oil industry also indicates that the diameter is frequently larger in clay formations than in the beds of sand. This, of course, depends on the relative extent of consolidation and induration of the sands and clays as it affects their ability to resist the erosion action that accompanies drilling operations. Figure 5 indicates the condition that might be expected where sands are fine, loose and less resistant than the clays. Generally wells are drilled with a bit an inch or so larger than the casing to assure easy stringing of the casing into the hole. Thus an annular opening is almost certain to exist throughout the entire length of the casing.

Ordinarily an attempt is made to seal outside the lower end of casings, either by driving the casing shoe into clay before continuing drilling, by pouring a cement plug around the casing shoe and drilling out the cement inside before continuing downward, or by using a packer on the lower end of the casing which expands when the shoe rests on bottom. In a hole that may be two or three times the diameter of the casing only the drive method seems reasonably sure of forming a tight seal, but even with this method there is no assurance that subsequent drilling, development or heavy pumping will not erode and break the seal.

When seals are used only at the foot of a casing penetrating several aquifers, the annular space between the casing and the wall of the oversize hole forms an open conduit between all aquifers above the casing shoe. Thus a deep well which is apparently giving no trouble may actually be responsible for serious vertical leakage between higher aquifers.

2. Development. By "development" is meant the removal of silt and sand from the assorted material around the well screen in order to produce a natural filter grading from coarse to fine material away from the screen. Development reduces the resistance to flow into the well and thus reduces the amount of drawdown required to produce a certain yield. It also permits the use of larger screen slots without being bothered by sand troubles during the initial use of a well. Development is accomplished by a variety of methods all designed to obtain a back and forth surging action which loosens the fine material and draws it through the screen where it can be bailed from the well. The vigorous surging action not infrequently causes erosion of the overlying clays around the casing above the screen and may contribute to failure of the seal at the casing shoe.

Figure 6 shows what may happen during the development of a well. In the article from which the illustration was taken it is suggested that the driller ask himself the following questions before proceeding with the job of development. 15/

"Just how does the well look down at the bottom?"

"What results do I want to get?"

"What is the surge plunger going to do when I operate it?"

15/ "Precautions When Using Surge Plungers in Developing Water Wells" Bulletin 1033, Edward E. Johnson, Inc., St. Paul, Minnesota. 1941.

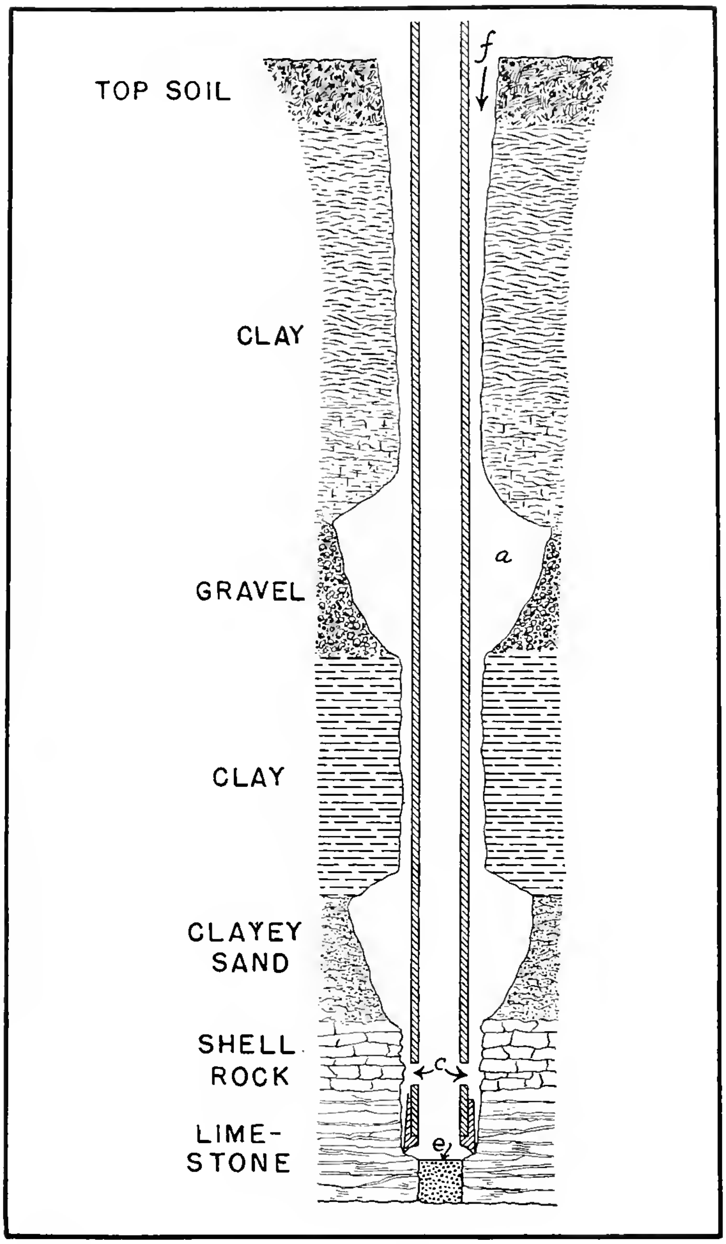

Fig. 5 Typical Cross-Section of a Well Drilled Through Sands and Clays. Illustration from "Correcting Defects" by Louis T. Watry; The Driller, Vol. 11, No. 5, p.7 May 1937.

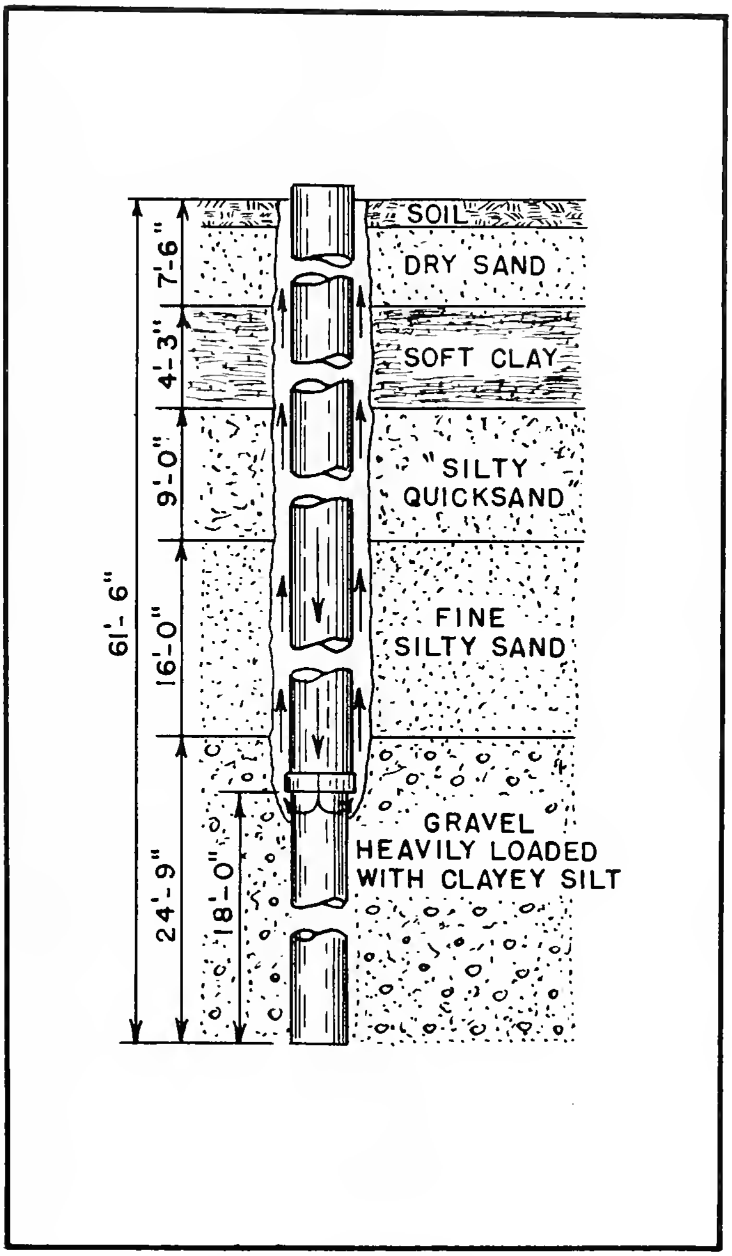

Fig. 6. Leakage Caused by Improper Development.

"How far do I want to carry the work?"

"What am I going to watch to determine if the work is going along O. K. and how long to continue?"

The thing ordinarily watched for is the appearance of considerable quantities of clay inside the screen. This is taken as an indication that the surging is eroding the overlying formation. Improper development of the type shown in Figure 6 produces a well that leaks from the outset.

3. Gravel Conductors. Gravel conductors are boreholes placed six to eight feet from the main well and sunk to the top of the aquifer to be used. Gravel is fed down the conductors to fill the cavity produced when sand and perhaps clay is pumped either during development or later during regular use of the well. Some wells in this area have been "taking" gravel for several years. Gravel conductors are usually cased with four or six inch pipe which is supposed to be sealed at some point in the clay above the aquifer developed. One or two conductors are used per well. Each conductor drilled in the area creates another possible source of vertical leakage, and since the conductors are kept full of gravel, they cannot readily be tested for leaks. When conductor casings are sealed only at the bottom, the annular space outside serves as a conduit between upper formations. The presence of more conductors than wells in some groups tremendously complicates the job of discovering exactly where leakage is occurring.

4. High Pumping Rates. The use of high pumping rates appears to have been responsible for much of the leakage. This is probably due both to the great erosive action around the well and to the high differences in head between upper and lower formations which accompany the high pumping rates. Practically all of the wells now giving most trouble are equipped with motor driven deep well turbine pumps that will deliver 400 to 700 gallons per minute. Air lift wells which normally discharge only 50 to 100 gallons per minute have not originally shown chloride contamination nearly so soon after going into operation, nor have the difficulties been as severe.

As examples of the difference in difficulties which may be due primarily to differences in pumping rates and methods, the experiences at the Continental Oil Company and the Royster Guano Company are cited here. The Continental Oil Company equipped two new wells with the turbine pumps in 1936 and two more in 1937. Deliveries for these wells ranged from 400 to 750 gallons per minute. In 1941 one well had to be abandoned because the strainer collapsed. In 1942 the three remaining wells were delivering water with chloride of 79, 117 and 560 p.p.m. respectively. The Royster Guano Company well 2000 feet away on land built out into the Patapsco River was drilled in 1919 and equipped with a reciprocating piston pump that delivers about 20 gallons per minute. In 1942 the water was of excellent quality and still retained

its natural chloride content of 8 p.p.m.

The contamination at the Continental Oil Company wells is a clear case of leakage for the chlorides vary erratically, the well with highest chlorides is farthest from the area of general contamination, and there are wells in all directions that produce uncontaminated water from the same aquifer. The problem at the Continental Oil Company is complicated by the presence of gravel conductors and 10 abandoned but unsealed wells.

5. Corrosive Shallow Water. The shallow waters are frequently contaminated with acids lost or wasted from industrial processes, or derived from the oxidation of sulphur bearing slag and other industrial wastes used for fill materials throughout the area. The high acid content of the soil in the Canton area has been mentioned on page 8. Since these acid and salt contaminated waters ordinarily have free access to the casings it is certain that the rate of corrosion is high. Few wells in the area are usuable for more than 15 or 20 years. At the Crown Cork and Seal Company's Highlandtown plant, well equipment is removed every year or so to patch large holes that have been eaten in the suction or discharge pipe of the pump. With wells unprotected by a cement shell, leakage through and down inside the casing as a result of corrosion is sure to occur sooner or later.

6. Earth Dam Experience. As a result of numerous failures of earth dams due to "piping", i. e., the development of open channels of flow along smooth conduits laid through embankments, this type of construction has had to be abandoned. Tunnels around the ends of earth dams are now used wherever feasible, but when a pipe must pass under the fill it has become accepted practice to place it in a trench excavated beneath the dam proper and to completely fill the trench and surround the pipe with a dense concrete. If it has been found that leakage along pipes through dams cannot be prevented with certainty by tamping impervious clays around them, it is not hard to believe that leakage will frequently occur outside well casings that are set in holes of unknown diameter, with a single uncertain seal at the bottom, and subjected to head differences of some 200 feet between the upper and lower formations. In fact it is almost necessary to propose the theory that the clays may gradually squeeze in against the casing, or that sand, silt and clay may be trapped in constrictions along the casing and naturally seal a well, in order to understand why all wells do not leak outside the casing.

The oil industry has recognized the seriousness of leakage down outside casings for some years and has developed successful methods of preventing this leakage in wells that run as deep as 10,000 feet. Prevention of leakage by proper use of cement grout is fully discussed in Section V.

Abundent evidence that leakage is actually occurring in wells throughout the Baltimore area is provided by the experiences and tests at the many large ground water using industries.

Leakage Experience.

With few exceptions all the industries in the Baltimore area that use large quantities of ground water have experienced difficulty with salt contamination, all of which can be attributed with a good deal of certainty to vertical leakage. The experience at the Western Electric Company and their almost complete success in correction of the difficulty is described on page 104. The situation at the Continental Oil Company has been mentioned above. Among the many other industries whose experiences might be cited as evidence that leakage is the cause of the contamination, those of the Bethlehem Steel Company, the U. S. Industrial Chemical Company and the Davison Chemical Company will be selected for discussion here because they have received most attention by the various investigators.

The Bethlehem Steel Company. Since the establishment of the old Maryland Steel Company upwards of 200 wells have been drilled at Sparrows Point of which about 67 are still in a usable condition. The wells are located in groups scattered over the Point and penetrate to one or the other of four major aquifers. Most of the early wells obtained water from the 100 and the 200 foot aquifers. The 100 foot formation became salty many years ago, probably from both leakage and entrance of river water at outcrops not far away. All the 100 foot wells and many of the 200 foot and deeper wells have been abandoned as salt appeared or other difficulties developed. Some of the earliest wells were left unplugged while others were filled by pouring concrete into the tops of the casings. Since about 1935 either clay or cement grout has been used to plug wells when abandoned and great pains have been taken to seal each well completely.

The situation at Sparrows Point has become extremely complex. There are wells in every group that are showing high chlorides and nearby wells to the same aquifers which produce uncontaminated water. The chlorides fluctuate widely and in many cases their movement is clearly affected by pumping various combinations of wells.

Mr. Henry C. Barksdale 13/ spent some time at the plant conducting chloride-pumping tests of the type described later, in order to determine sources of leakage. His diagnoses of the difficulties are briefly summarized to illustrate a few of the many varieties of

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13/ Henry C. Barksdale "Ground Water Conditions at the Sparrows Point Maryland Plant of the Bethlehem Steel Company". Confidential Report to the U. S. Department of Interior Geological Survey, March 29, 1941.

leakage that may occur. Whether or not these diagnoses are correct may only be finally determined on the basis of more extended tests than time permitted Mr. Barksdale to make. The following statements should, therefore, be considered as having illustrative value only.

Town Water Wells to the 200 foot level are believed to be contaminated by leakage at the Old Town Wells 2000 feet away. There are eleven town water wells four of which tap the 200 foot aquifer and the balance the 300 foot aquifer. All the deeper wells produce uncontaminated water. There are 27 old town wells, 14 of which reach to or beyond the 200 foot formation. The four which are not abandoned are rarely used.

40-Inch Mill Wells range from 210 to 667 feet in depth. Of the eight wells in the group only No. 5 has caused trouble. It was believed to have been originally drilled to 438 feet and was later changed to 287 feet depth. The old 8-inch casing was cut at 283 feet and removed and a new 6-inch casing with screen was set in the well. Tests seemed to indicate leakage down the annular space outside the 6-inch casing.

Hot Strip Mill wells are nine in number. Wells 1, 5 and 8 are to the 230 foot formation; 2, 4 and 9 to the 330 foot formation and 3, 6 and 7 to the 680 foot strata.

There was no indication of leaks through the casings. Diagnoses were as follows: No. 9, salt water entering through or around one of the gravel conductors. No. 4, contaminated by salt water traveling along one of the gravel conductors of well No. 6. No. 5, salt water entering through or around one of its gravel conductors.

Sheet Mill Wells, two in number, both contaminated. No. 1 is 177 feet deep and No. 2, 228 feet deep. Both are believed to be contaminated by salt water leaking down the annular space between the casing and the rotary drilled hole and also down the gravel conductors.

Wire Mill Wells. Of the 12 wells in the group at this mill two have been abandoned and only No. 8 which is 618 feet deep is giving trouble. Tests indicate leakage through a perforation in the casing.

U. S. Industrial Chemical Company. The U. S. Industrial Chemical Company has two plants, one in Fairfield and one in Curtis Bay. Seventeen wells have been drilled at the Fairfield Plant of which three are in use at present. No chloride difficulties have developed at the Fairfield plant. Twenty-eight wells have been drilled at the Curtis Bay Alcohol Plant of which six are still in use. Salt contamination problems had developed in this plant prior

to 1920 for in that year Dr. Joseph T. Singewald was called in to study the situation and suggest remedial measures.

Table XII shows chloride contents prior to and during 1920 and in 1942 when waters were spot tested. All the wells used in 1920 have since been abandoned. The high chloride content of water in well 3929 which taps the 300 foot level that had shown signs of contamination in 1920 indicates leakage to this level has continued to increase. The 357 foot wells show a rise to 45 p.p.m. over the 4 or 5 p.p.m. for wells 7 and 9 in 1920. The problem at the U. S. Industrial Alcohol Plant has not received intensive study in recent years because sufficient fairly low chloride water is still produced.

The Davison Chemical Company. There are eight wells at this plant. Nos. 1 and 6 were air lift wells drilled about 200 feet from the Bay and Nos. 7 and 8 are deep well turbine pumped and are about 700 and 600 feet farther inland. Wells Nos. 1 and 5 were abandoned and an attempt was made to seal them with cement. Unfortunately, the procedure used is unknown. Well No. 6 yields water with a chloride content around 300 p.p.m. and is therefore not much used. Well No. 8 which is between Wells Nos. 6 and 7 has delivered water with increasing chloride content since the summer of 1940. Tests carried out at this plant by Mr. Barksdale 13/ indicated that there were no leaks in the casings of wells Nos. 6, 7 and 8, that the entire area around well No. 6 was contaminated and that salty water accumulated around the top of the screen in well No. 8 when it was shut down. These results were interpreted to indicate the movement of salty water from the old well field where it was believed one or more of the plugged wells still leaked seriously. The tests on Well No. 8 could as readily have been interpreted as indicating leakage down outside its own casing but this presumably was assumed impossible because the casing had been grouted in place. However, vertical leakage occasionally occurs in grouted wells. Testing with different pumping rates as described later might throw light on the situation. Apparently Well No. 7 taps only the lower of two aquifers which are separated by a narrow band of clay and the salt water is coming into Well No. 8 through the upper of these two. No perceptible increase in chlorides has ever been observed in Well No. 7.

The appearance of chlorides in certain wells while others nearby and to the same aquifer are free of contamination is

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13/ Henry C. Barksdale "Ground Water Conditions at the Sparrows Point, Maryland Plant of the Bethlehem Steel Company". Confidential Report to the U. S. Department of the Interior, Geological Survey, March 29, 1941.

TABLE XII

Chloride Content of Well Waters at the
U. S. Industrial Alcohol Company Plant

Well No.*	Probable Present No.	Depth	11/14/19	2/23/20	2/24/20	2/27/20	3/1/20	4/13/42
				p.p.m. chloride ion				
3	(749 (751 or (752	300	4.5		26	27		
4	(747 or (750	297	35	48	28	28		
5	739	285	8		25	26	39	
6	746	197	44		40	68	65	
7	740	341	15		5	3	5	
8	748	293	39			4	28	
9	741	341				3	4	
10	742	285			24	28	28	
11	743	285				23	51	
12	1154	431					4	
	1323	357						45
	1326	327						16
	1468	368						1
	3700	227						35
	3929	300						320

* Well Numbers used in the Singewald Report. Joseph T. Singewald, Jr. Report on the Curtis Bay Water Supply for the U. S. Industrial Alcohol Company, December 8, 1920.

characteristic of all well fields along the Patapsco River below Canton and Locust Point. This fact alone is a fairly clear indication that leakage is responsible for the chloride difficulties. That leakage is responsible can be reasoned from the knowledge of what occurs when wells are drilled by the methods commonly used in the area. Finally the fact that vertical leakage inside or outside of casings must be responsible for the chloride tests that have been made.

In order that the methods for testing wells to determine the source of leakage will be more widely understood and adopted, they are elaborated here.

Testing for Chloride Leakage

The methods at present in use for testing wells to determine the source and manner of entrance of the high cloride water may be divided conveniently into four classes. 1) Pumping and chloride analysis methods. 2) Resistivity methods. 3) Current meter methods. and 4) Geochemical analysis methods.

The pumping and chloride testing methods are relatively straight forward and can be applied to any well if apparatus is available for determining the chloride content of samples taken. However, correct diagnosis of the cause of leakage from the test data obtained requires careful analysis. Therefore, typical leakage situations and the resulting time-chloride curves are discussed in detail.

The resistivity methods provide a very accurate means of locating leakage through casing perforations but special cells and cables are required. There is believed to be some possibility of determining the source of chloride water by correlation of resistivity and chloride analyses. An investigation of this possibility is described.

The current meter method depends on the measurement of vertical movement of the water column inside the casing by use of a very delicately balanced propeller. The equipment is expensive and must be handled with care. It is useful for establishing the point, the direction and the amount of leakage through casings. Both resistivity and current meter equipment will be available for use in carrying on the State and Federal cooperative study. The resistivity and current meter methods will not be discussed because the equipment is available only to specialists in ground water and because it is used for the relatively simple job of discovering leakage through casing perforations.

Geochemical analyses methods seem to have many promising possibilities in connection with determining the source and amount of leakage and for establishing the interconnection of aquifers in different areas. They have the disadvantages of being little understood and of requiring a complete mineral analysis of the water.

Pumping and Chloride Testing.

Pumping and chloride analysis tests are commonly carried out as follows. The well is allowed to stand idle over night or for several hours, after which it is started up and the water sampled every few seconds for several minutes, then at increasing time intervals up to several hours. The samples are analyzed for chlorides and the time-chloride curve is plotted for the test. If the rate of pumping is measured it is possible to estimate the point in the casing or in the gravel from which the water is derived after any time interval from starting the pump. The estimate of the location of the most highly contaminated water is used to diagnose the source and manner of chloride contamination. The test results will vary depending on the length of shut down, the rate of pumping and whether or not nearby wells are running, as well as on the actual leakage occurring in or around the well. These things, therefore, must be taken into account. By conducting several tests in which the length of shut down, the pumping rate and the operation of adjacent wells are varied a great deal of significant information may be obtained.

In order to prophesy the time-chloride curves which will be produced by various types of leakage a well will be assumed which passes through a shallow highly salt contaminated aquifer, and draws its supply from a deeper strata.

Since the direction of leakage during shutdown is governed by the static levels in the two aquifers it is necessary to further assume that the static water level stands at a greater distance below the ground in the deeper aquifer. This is the normal state of affairs because when the shallow strata become contaminated by leakage the lower ones are pumped more heavily.

The static levels during shutdown have a profound effect on the time-chloride curves. If the static level in the lower formation should stand above that in the upper and if this relative head situation is reversed when pumping starts, time-chloride curves will result which are entirely different than those for the normal conditions assumed above.

Leakage Inside the Casing. Salt water entering a perforated casing will move down the well displacing and mixing with the fresher water left in the casing when the pump was stopped. Water above the leak will float on the salty water entering the well and its chloride content will remain unchanged during the shutdown. If the leak is below the pump intake, the time-chloride curve will rise sharply after the fresh water above the leak has been pumped from the well. The volume of water pumped before the appearance of high chlorides will equal the capacity of the casing between the static and dynamic levels plus the capacity of the casing between the foot of the riser pipe and the leak. To this must be added the capacity of the riser

pipe between the dynamic level and the foot of the riser pipe in order to allow for the time required to remove the additional fresh water inside the riser. The time measurement should be started when water first appears at the sampling point.

Sample computations of the distance from the foot of the riser to the leak are explained in Appendix V.

If the leak is above the lower end of the riser, the volume of water pumped before the appearance of high chlorides will equal the internal capacity of the riser pipe below the static level. In this case the level at which the well is leaking cannot be estimated from the time-chloride curve.

If computations indicate that salt water is entering near the bottom of the well, leakage outside the casing should be suspected.

Leakage Outside the Casing. Salty water leaking down outside the casing will accumulate in and around the screen at the bottom of the well unless pumping at a nearby well is pulling water through and past the well under test. The fresher water left inside the casing will normally float on the salty water and prevent the latter from rising up the casing. If the outside casing leak is large and the static level in the contaminating aquifer is considerably higher than that in the contaminated aquifer, salt water might rise inside the well for a short distance. In fact, the water level in the well will be compelled by heavy leakage to rise above the true static level for the lower aquifer. The phenomena are the exact reverse of "Drawdown".

The full cycle of events is as follows. When the pump is stopped, contaminated leakage water continues to flow into the pure water aquifer, filling the aquifer around the leak and forcing the pure water back away from the well. On starting the pump the casing water is first discharged. During this period the chlorides remain constant at the value when the pump was stopped. The leakage water then appears and the chlorides rise rapidly to a maximum, then decrease gradually for a short period as the lower aquifer is cleared of salty water that entered during the shutdown, and finally decrease rather rapidly to a constant amount. See Figure 7. The length of period of gradual decrease after the rise to a sudden peak will be longer the greater the length of the shutdown period.

Decrease in the rate of pumping at which the test is made will spread the time scale but should not materially affect the maximum peak chloride value. The final constant chloride value will however depend on the pumping rate.

For artesian aquifers the specific delivery is approximately constant for various drawdowns, that is, the increase in yield per foot of drawdown is constant. Furthermore, unless the leakage rate

is very high the drawdown in the upper contaminated formation should be small compared with that in the well. If the leak delivers water to the well by turbulent flow the rate of leakage will vary as the square root of the ratio of differences between the static level in the contaminating aquifer and the dynamic level in the pumped well, while the flow of fresh water from the aquifer will vary directly with the changes in dynamic level or drawdown. Thus as pumping rates increase the chloride content of the water will drop rapidly. Of course the higher pumping rate may gradually enlarge the leak and further damage the well.

In Appendix VI examples are worked out which show the effect of different pumping rates on the chloride content of the mixed leakage and fresh water.

Comparison of measured and computed chloride contents for different pumping rates should be very helpful in diagnosing the source, type and amount of leakage. If measured and calculated values of chloride changes do not agree, this information can be used with the time-chloride curves for further analysis and interpretation. For example, if the leakage rate is high, the approximate estimate of chloride changes based on an assumed low leakage will give a chloride value for the high pumping rate that is greater than the measured value. Furthermore, it is possible to obtain additional information by varying the length of shutdown to obtain different time-chloride curves from which the rate of leakage can be estimated by comparing the areas under the high part of the curves. This information can then be used to check the leakage rates estimated from studies of the chloride variations with changes in pumping rates.

If computed and measured values for chlorides at various pumping rates differ widely and erratically, a complicated situation which may involve the effect of leakage and pumping at other wells than the one tested is indicated.

With ordinary leakage outside the casing pumping of nearby wells while the tested well is shut down may pull the chloride water away from the screen. The situation would be indicated by a rise in chlorides at the pumped wells and by a marked reduction in the critical chloride increase on starting the pump in the leaky well. For this reason wells within several hundred feet of the tested well should not be pumped during the first tests. Then if desired the other wells might be run to determine the effect on the movement of chlorides.

<u>Leakage at Other Wells</u>. If the time for appearance of high chlorides after a shutdown is greater than that required to pump out the casing the leak must be at some other well or in one of the gravel conductors. Of the many possible situations, the follow-

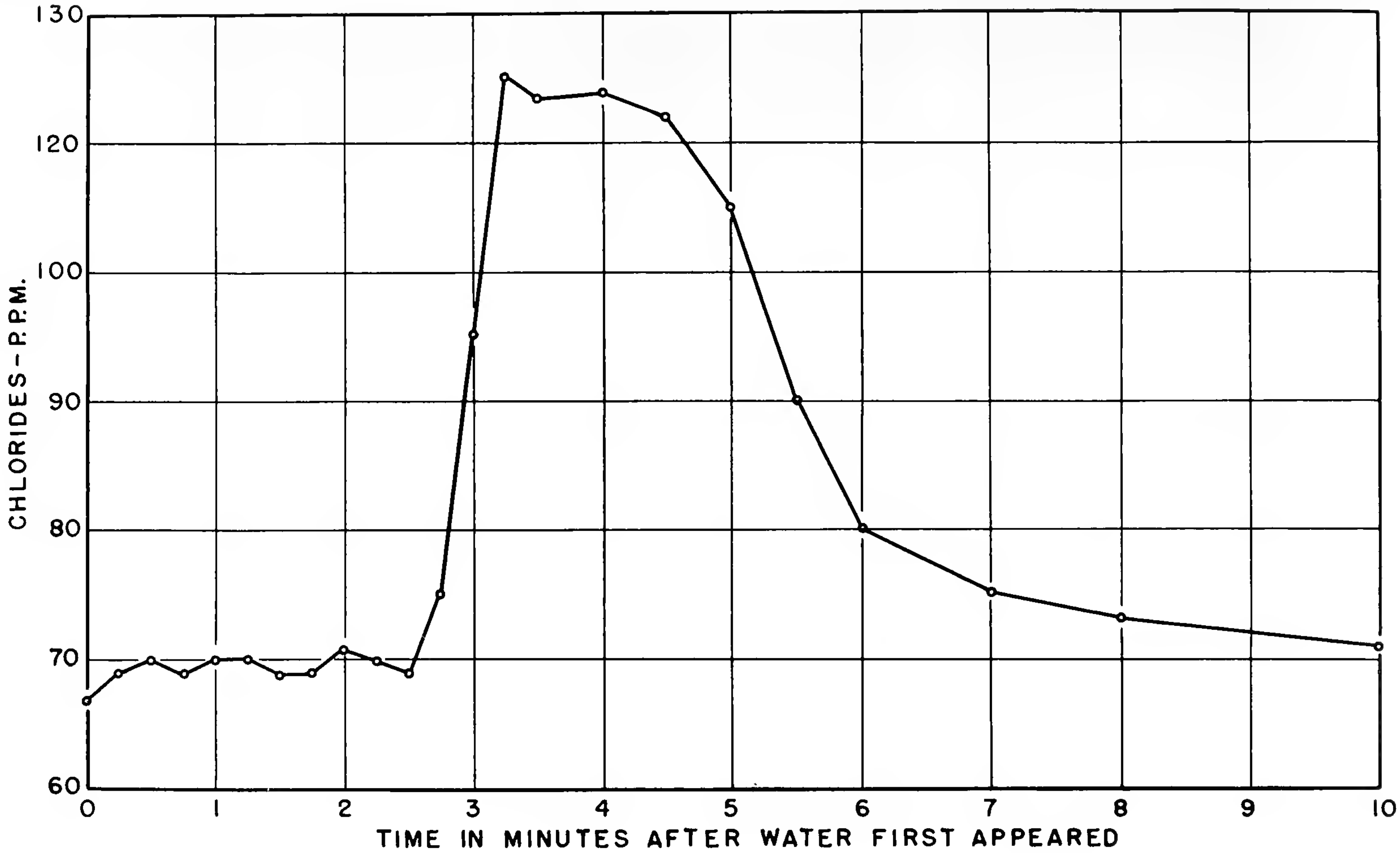

Fig. 7. Typical Time-Chloride Curve.

ing only will be considered. 1) Leakage down the wells own gravel conductor. 2) Leakage down an abandoned well or conductor or down outside the casing of a well or conductor that penetrates to a deeper aquifer. 3) Leakage down a used well or conductor that ends in the same strata as the well tested.

Leakage down a well's own gravel conductor is evidenced in the time-chloride curve by the length of lag in the appearance of high chloride water. If the thickness of the aquifer and the pumping rate are known the time required to evacuate the ground out to the conductor can be estimated fairly accurately. Comparison of this time with the time for chloride appearance will indicate whether or not the conductor should be suspicioned. Varying the length of shutdown will allow the chloride water to spread so high chlorides should appear in less time the longer the shutdown. On increasing the pumping rate there will be a much smaller percentage drop in chlorides if the conductor is leaking than if the well itself leaks. This can be figured out if the dynamic level in the conductor is measured. Pumping nearby wells in various directions one by one should move the chlorides one way or another in the ground. The direction of the leak could then be determined from study of the various time-chloride curves taken.

Leakage down abandoned wells or conductors, or outside casings of deeper wells and conductors, is indicated by the long time-lag in the chloride rise after a shutdown, by the very slight effect on chlorides of changes in pumping rates and by the great effect of running other wells. When this situation is indicated attempts should be made to localize the source by pumping various wells or combinations of wells. If several time-chloride curves can be obtained for different wells operated singly, the various time values can be used to determine the approximate location of the leaking well. All that is necessary is use of the fact that the time for arrival of the accumulated high chlorides increases as the square of the distance of these chlorides from the well tested. This makes possible the computation of the ratios of the distances to the source from the tested wells. Then by trial a length scale can be selected which will cause all the distance arcs struck from tested wells to intersect. If different pumping rates are used at the different wells during each test this must be taken into account. By such tests the field of possibilities can be narrowed until the responsible well is located. This well or conductor can then be tested and repaired by methods described later.

Before leaving this subject the type of time-chloride curve produced when the static level in the upper or contaminated formation is at a lower elevation than that in the fresh water aquifer, should be mentioned. Under these circumstances the leakage will be upward during shutdown and water from the lower strata will freshen the upper. The time-chloride curve would show a long lag probably quite

similar to that produced by leakage to the lower aquifer at a distant well. However, the difference can be told, for the longer the shutdown the greater the lag and this is the opposite of the behavior when leakage is downward at another well to the same formation. Moreover, after downward flow is reestablished in the leaking well, the chlorides will vary with changes in the pumping rate as in any leaking well.

The above discussions and proposed tests are elaborations of the idea of shutdown and pump testing and time-chloride testing that has been in use for some years. No record has been found of past use of the variations in chlorides with changes in pumping rates for determining sources and rates of leakage. No doubt the simple ideas involved have been applied before. Unfortunately, time and means were not available to put the ideas presented into use by making a series of tests of leaky wells. This should in no way detract from their value, for there is no way to observe visually what is taking place in the ground in order to check the analysis of a set of time-chloride and pump test data. The only final assurance of correct diagnosis is through multiplicity of tests, and through final success in attempts to correct the leakage.

Resistivity Tests

Either resistivity or conductivity measurements can be used in several ways in connection with chloride contamination studies. These are: 1, for the location of casing leaks; 2, for rapidly analyzing for chlorides; and 3, in connection with other analyses for determining the origin of the contaminating water. The use of resistivity or conductivity tests for locating casing leaks has been mentioned earlier. The method is simple and has been widely employed. The discussion is, therefore, confined to the value of resistivity measurements as a means of chloride analysis, and to the significance of resistivity tests when compared with ordinary chemical analysis of chlorides. As background for this report of tests, the theory of measurement and calculation of resistivities is reviewed in Appendix VII.

In the present work specific resistance, i.e., the resistance in ohms of a unit centimeter cube, was measured with an Industrial Instruments Company, Model RC, conductivity bridge and conductivity cell. This equipment was loaned by the Bethlehem Steel Company. It consisted of a vacuum tube wheatstone bridge with an electric eye and a cell with platinum blacked electrodes. The cell constant, which was actually 0.998, was assumed to be unity. Thus the bridge was assumed to read directly the specific resistance in ohms.

The resistivities of pure sodium chloride solutions of different concentrations were calculated and checked by measurement with the above equipment. The procedure used is described

in Appendix VII and the values obtained are plotted in Figure 8 for comparison with the chlorides and resistivities of natural waters.

A sample of Patapsco River water was then diluted to various chloride concentrations and the specific resistances determined. This water is probably the original source of most of the contaminating chlorides. The results are shown in Table XIII and are also plotted in Figure 8. The close agreement of the resistivity measurements for Patapsco River water with those for pure sodium chloride solutions indicates that the conductivity of the river water is due primarily to the presence of chlorides. Since the natural ground waters in the area have a very low conductivity it should, therefore, be possible to determine whether or not the contaminating waters are derived directly from the river or whether they have picked up additional salts in circulating through the ground. It may be reasoned that if the contaminating river water is entering an outcrop directly and moving down the strata or if it takes a very short underground path from the river to a leaking well, there will be little opportunity to pick up additional salts. In this case the resistivity of the contaminated well water should be close to that for a pure sodium chloride solution of the same chloride ion content. On the other hand if a well is contaminated by a mixture of river water and shallow ground water which has picked up acid and salts other than sodium chloride, the resistivity should be much less than that of a pure NaCl solution with the same chloride ion content. Tests show that this is probably true.

In Table XIV are shown the pH values, chloride contents, and resistivities for spot samples of a number of active wells in the area. The values are plotted in Figure 8 and identified by the line number column (1) in Table XIV.

Consider first these points lying close to the theoretical chloride - specific resistance curve. No. 17 is the repaired Western Electric well close to the river. There is little doubt that the chlorides followed a short underground course to reach the leak in this well. Nos. 31 and 33 are the Continental Oil Company Wells where serious chloride leakage is developing. Nos. 45 and 46 for the Standard Wholesale Phosphate Company both show about equal proportionate deviation from the theoretical line. This is true of other well groups and indicates the source of contamination of all wells in such groups must be the same. Nos. 2, 22 and 47 are all for wells close to the river where entrance of chlorides may be fairly direct. No. 22, the Maryland Drydock well shows no indication of the effect of surface contamination. This well is the only one in the area that is suspected of indicating an extension down the dip of the area of widespread contamination. This particular test might indicate such an extension or might be the result of very direct leakage from the river which is only 100 feet away.

TABLE XIII

Resistance and Chloride Content
of Patapsco River Water
at Mouth of Baer Creek.

Sample taken 200 feet SW of west end of railroad bridge at Sparrows Point. Sampled at the beach. pH 8.1. Dilutions made with distilled water and tested for specific resistance.

Measured Chloride ion content p.p.m. (1)	Calculated Chloride ion content p.p.m. (2)	Temp T C	r at T ohms	r at 18 C ohms
(1)	(2)	(3)	(4)	(5)
5000	5000	22	70	77
---	2000	23.8	160	183
---	1000	24.1	305	362
---	500	24.1	575	664
---	200	24.6	1850	2140
---	100	24.5	2700	3150
50	50	24.3	5250	6080
11	10	24	21300	24500

(1) These values measured using silver nitrate.

(2) These figured from the first value in Column (1) and from the dilution ratios.

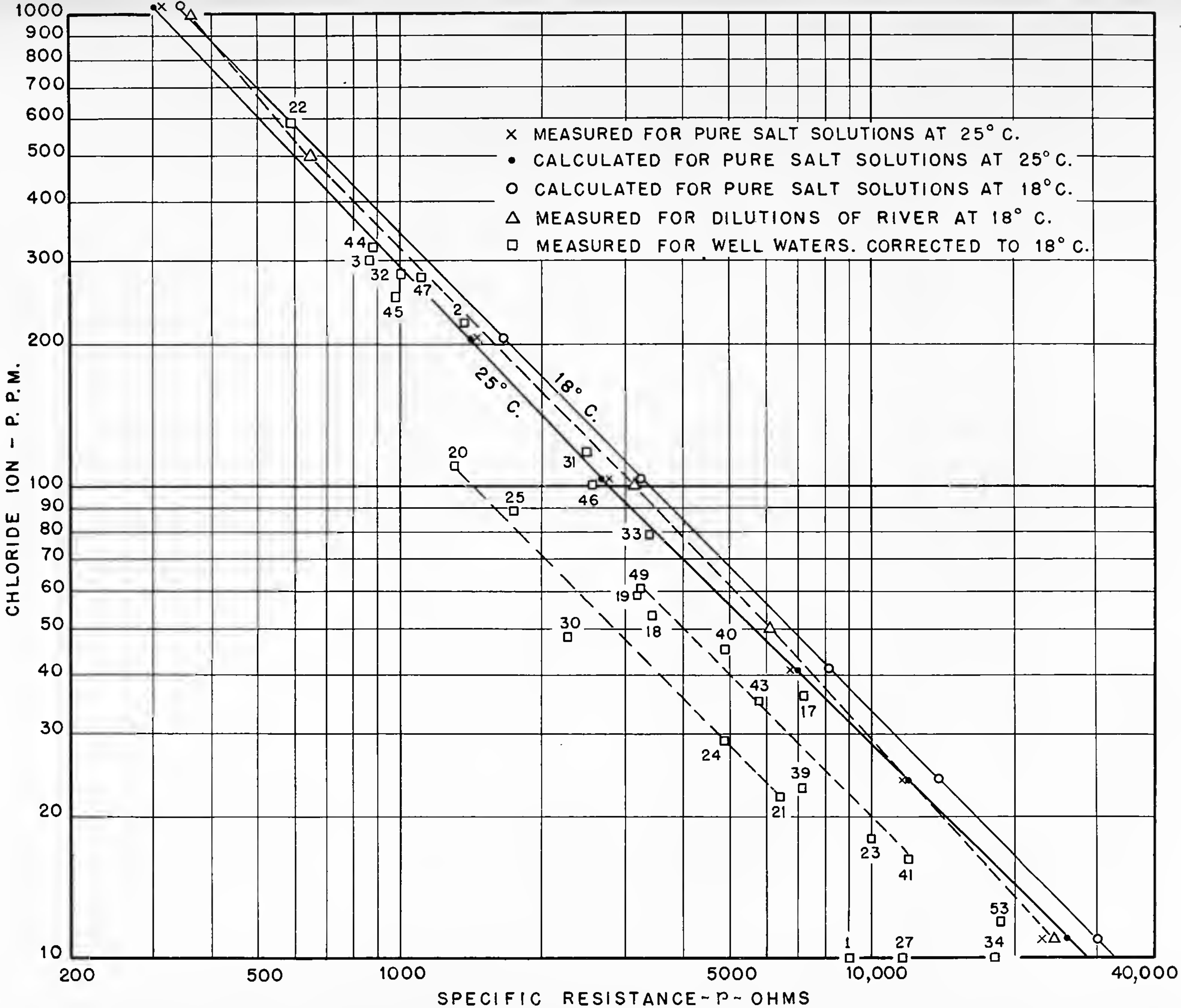

Fig. 8. Specific Resistance vs. Chloride Ion Content of Various Solutions and Well Water Samples.

TABLE XIV

RESISTANCE, CHLORIDE AND pH TESTS
of ground water in the Baltimore Area.

No.	Company	Well No.	Date	pH	Cl p.p.m.	Laboratory Tests: Temp. C	Laboratory Tests: Ohms Resist. T C	Laboratory Tests: Ohms Resist 18 C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Bethlehem Steel Co.	1 FH	9/29/42		10	18	9,000	9,000
2	" " "	2 FH	"		220	18	1,375	1,375
3	Carr-Lowry Glass Co.	1	"	7.4	300	17	885	863
4	" " "	2	"	8.4	1430	16	232	220
5	Baugh Chemical Co.	#4 bldg.	9/30/42	5.2		18	575	575
6	" " "	Acid Plant	"	5.4		19	420	430
7	National Brewing Co.	#3	"	5.0		16.5	500	480
8	" " "	1	"	7.6		17	800	780
9	Baltimore Pure Rye Co.	1	"	5.2		17	29,000	28,000
10	" " "	2	"	5.1		16	30,000	28,000
11	Camp Holabird	270	10/1/42	5.4	2	16	47,000	44,700
12	Federal Yeast Co.	1	"	5.2	2	16	48,000	45,600
13	" " "	2	"	5.4	3	16	55,000	52,300
14	Chemical Pigment Co.	1a	"	5.3	4	23	30,100	34,000
15	(Same Well)?	1b	"	6.0	3	23	10,200	11,500
16	Western Electric Co.	1	10/2/42	5.3	4	20	33,000	34,700
17	" " "	2	"	5.0	36	19	7,000	7,200
18	S & K Co.	2	"	4.7	53	21	3,200	3,440
19	"	3	"	5.3	57	21	3,000	3,220
20	C.C. & S.	1	"	3.8-	110	23	1,175	1,320
21	"	3	"	5.0	22	23	5,700	6,400
22	Maryland Drydock Co.	1	10/3/42	4.8	590	23	525	590
23	Consolidated Gas & Electric Co.		10/7/42	6.0	18	18	10,000	10,000
24	Monarch Rubber Co.		"	5.1	29	18	4,900	4,900
25	Penna. Water & Power Co.		"	6.8	89	18	1,750	1,750
26	Frankfort Distillery	1	"	5.2	9	18	14,300	14,300
27	" "	2	"	5.2	10	18	11,700	11,700
28	Eastern Rolling Mill	5	"	5.0	6	18	24,000	24,000
29	" " "	7	"	5.2	6	18	15,300	15,300
30	Baltimore Transit Co.	Bear Creek	"	6.2	48	18	2,270	2,270

TABLE XIV (Continued)

RESISTANCE, CHLORIDE AND pH TESTS
of ground water in the Baltimore Area

No.	Company	Well No.	Date	pH	Cl p.p.m.	Laboratory Tests: Temp. C	Ohms Resist T C	Ohms Resist 18 C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
31	Continental Oil Co.	5	11/6/42	4.9	117	14.5	2,700	2,500
32	" " "	6	"	4.8	280	15	1,100	1,000
33	" " "	7	"	5.0	79	14	3,750	3,400
34	U.S.Ind. Chem. Co.	5025	"	4.7	10	14.5	20,000	18,300
35	" " "	6844	"	4.8	8	14	23,500	21,200
36	Royster Guano Co.		"	5.7	8	15	19,500	18,000
37	Arundel S. & G. Co.		"	5.9	4	15	47,000	43,500
38	Brooklyn Chem. Co.		"	5.5	4.5	15	31,000	28,600
39	Pan American Oil Co.		"	6.0	23	15	7,700	7,100
40	U.S.Ind. Alk. Co.	1323	11/13/42	4.3	45.5	17.5	5,000	4,900
41	" " "	1326	"	4.7	16.3	17.5	12,250	12,000
42	" " "	1463	"	5.2	1.0	17.5	57,500	56,500
43	" " "	3700	"	4.8	35	18.0	5,750	5,750
44	" " "	3929	"	4.2	320	18.0	875	875
45	Std.Whl.Phos.& Acid Co.	1941	"	4.1	253	17.5	1,000	980
46	" " "	1925	"	4.8	100	17.5	2,600	2,560
47	Davison Chem. Co.	6	"	5.7	277	18.5	1,100	1,120
48	" " "	7	"	6.0	2	18.5	21,500	22,000
49	" " "	3	"	4.2	60	18.5	3,200	3,260
50	Chas. S. Walton Co.	N.W.	"	6.0	4	17.0	28,000	28,500
51	" " "	S.E.	"	4.8	1.5	17.5	47,000	46,000
52	" " "	N.E.	"	5.8	3.5	17.5	34,000	33,400
53	" " "	N	"	5.6	12	17.5	19,000	18,700

All the wells of the U. S. Industrial Alcohol Company except No. 44, that is, Nos. 40, 41 and 43, fall along a line parallel to the theoretical indicating similarity of origin. The same is true for the wells in the Highlandtown area, Nos. 20, 21, of the Crown Cork and Seal Company, No. 24 the Monarch Rubber Company, No. 25 the Pennsylvania Water and Power Company, and Nos. 18 and 19 the Schluderberg Kurdle Packing Company. The latter group of points indicates that these wells are not contaminated by river water alone, and thus that shallow waters, highly contaminated with acids and salts, are leaking into these wells, either locally or into the aquifers between the wells and the river. The similarity of the water from these widely scattered wells, suggests general contamination of the aquifer through leaking wells some distance toward the Patapsco.

The results presented here are not considered at all conclusive and are set forth only to indicate that the very simple procedure of testing both chlorides and resistivities may give information that can be used to advantage with other evidence when studying the contamination problems in the area. The graphical representation used here constitutes a highly simplified geochemical analysis.

Geochemical Analyses

A geochemical analysis as applied to ground waters is any method of comparing or studying the chemical constituents of water to determine its origin, or the origin and proportion of the various component waters of which the sample is a mixture. The possibilities for using these methods for ground water studies in this area to determine the source of contaminating waters and to determine the interconnection of aquifers both horizontally and vertically are very good. The methods have the disadvantage that a large amount of work is involved in making the chemical analyses and in reducing and plotting the data so that they may be studied. The photometric cell principle aids somewhat in this application by using the recently developed chloride testing equipment, proven practicable and satisfactory in many areas. On the other hand, the use of geochemical graphs for interpretations is a great improvement over the common procedure of attempting to conceive the significance of a series of chemical tests merely by looking at the results.

In the present studies the possibilities for geochemical analyses could not be fully explored because of the lack of time and basic data. Only one chemical analysis that gave all the information needed for geochemical studies was found during the course of the work. Nevertheless the principles of geochemical analysis are discussed in detail in Appendix VIII because of their value and because by adding a relatively few additional chemical tests to those commonly used by the industries in making water analyses, the results can be used for geochemical studies.

In many of the existing water analyses it would not have required much additional work to run the full set of tests needed to make the results usable for geochemical interpretations. Although hundreds of ground water samples from the area have been analyzed only a few sets of data are complete. The very promising possibilities of applying geochemical methods in the study of ground water problems in the Baltimore Industrial Area must wait on the time when complete chemical analyses are obtained.

All the foregoing discussion of chloride problems has dealt only with the discovery of the source, the manner and the amount of chloride contamination of fresh water aquifers. The methods available for preventing or correcting these difficulties are taken up in the next section of this paper.

SECTION V

THE USE OF CEMENT IN WELL CONSTRUCTION REPAIR AND SEALING

The proper use of cement grout in the construction of new wells and for the repair and sealing of old or abandoned wells is perhaps the greatest single thing that can be done to correct the ground water difficulties occurring in the Baltimore Industrial Area. Cement grouting of new wells to prevent vertical leakage either upward or downward between formations in deep oil wells has become a highly developed art. Unfortunately, the methods successfully used by the young and energetic oil industry are only now being adopted by water well drillers.* In recent years some State Boards of Health have taken steps to encourage the use of cement grouting to prevent leakage of shallow contaminated ground waters into the pure sources below. The State of Wisconsin has led all others in this field and has established in the Bureau of Sanitary Engineering a Division of Well Drilling. Mr. Louis T. Watry, Well Drilling Supervisor of this Bureau has published numerous articles on the use of cement grout.

In the oil industry the Halliburton Oil Well Cementing Company, Duncan, Oklahoma, is one of the leading concerns in business of cement grouting new and old oil wells.** Their claims for the advantages of cementing are: 18/

"A properly cemented well - - - -

1. Provides a permanent casing shut-off regardless of formation.

2. Protects the producing formation from upper waters.

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*/ As examples of techniques used in oil well investigations that have not been adopted by water well drillers so far as is known, modern methods for electrical logging and side wall sampling are illustrated here. Figures 9, 10 and 11. Both these techniques could be used to advantage in water well investigations. However, since their use does not pertain to the problem in hand, no details are presented. Numerous other devices used by the oil industry are illustrated in the subsequent pages.

**/ Equipment used by the Halliburton Oil Well Cementing Company, The Lane Wells Company, The Schlumberger Company and others that operate in the oil fields is illustrated in this section.

18/ Catalogue No. 10, The Halliburton Oil Well Cementing Company, January 1939.

3. Protects the casing, where cemented, against collapse from external pressures.

4. Prevents corrosion, the cement keeping highly mineralized fluids away from the casing.

5. Prevents shifting formations, the cement forming a tight seal between the hole and the casing.

6. Prevents migration of fluids from one formation to another."

The Wisconsin Division of Well Drilling concludes that: 19/

"Properly constructed and maintained, the drilled and cased type of wells should be permanently free of pollution. Failure to seal the annular space is largely responsible for the disproportionate number of wells of this type found polluted despite proper precautions applied at the upper terminal and sufficient depth of the lower end of the casing pipe".

The objective in cement grouting of all new wells should be to obtain a continuous dense shell of cement surrounding the entire well casing and blending intimately with the earth or rock wall of the hole. The thickness of such shells should be at least one inch and preferably two or more inches. Although a great many ingenuous ways have been devised for placing the grout to form this shell, all the possibilities have not been exhausted.

The use of cement grout to repair old wells that are leaking badly is more difficult, for even with the most thorough testing it may be impossible to determine the location and size of all cavities to be filled with grout. In repairing old wells there are apt to be a good many failures and failure on the first attempt will generally mean abandonment and complete sealing of the well. When using cement grout to repair a leaky well a great deal of careful thought must go into making tests, analyzing the situation and planning the work.

The complete sealing and plugging of abandoned wells presents no great difficulties. Nevertheless, some of the past attempts have failed because it has been assumed that filling the old casing with cement constitutes sealing of the well.

19/ "Methods of Cement Grouting for Sanitary Protection of Wells" Wisconsin State Board of Health, July, 1939.

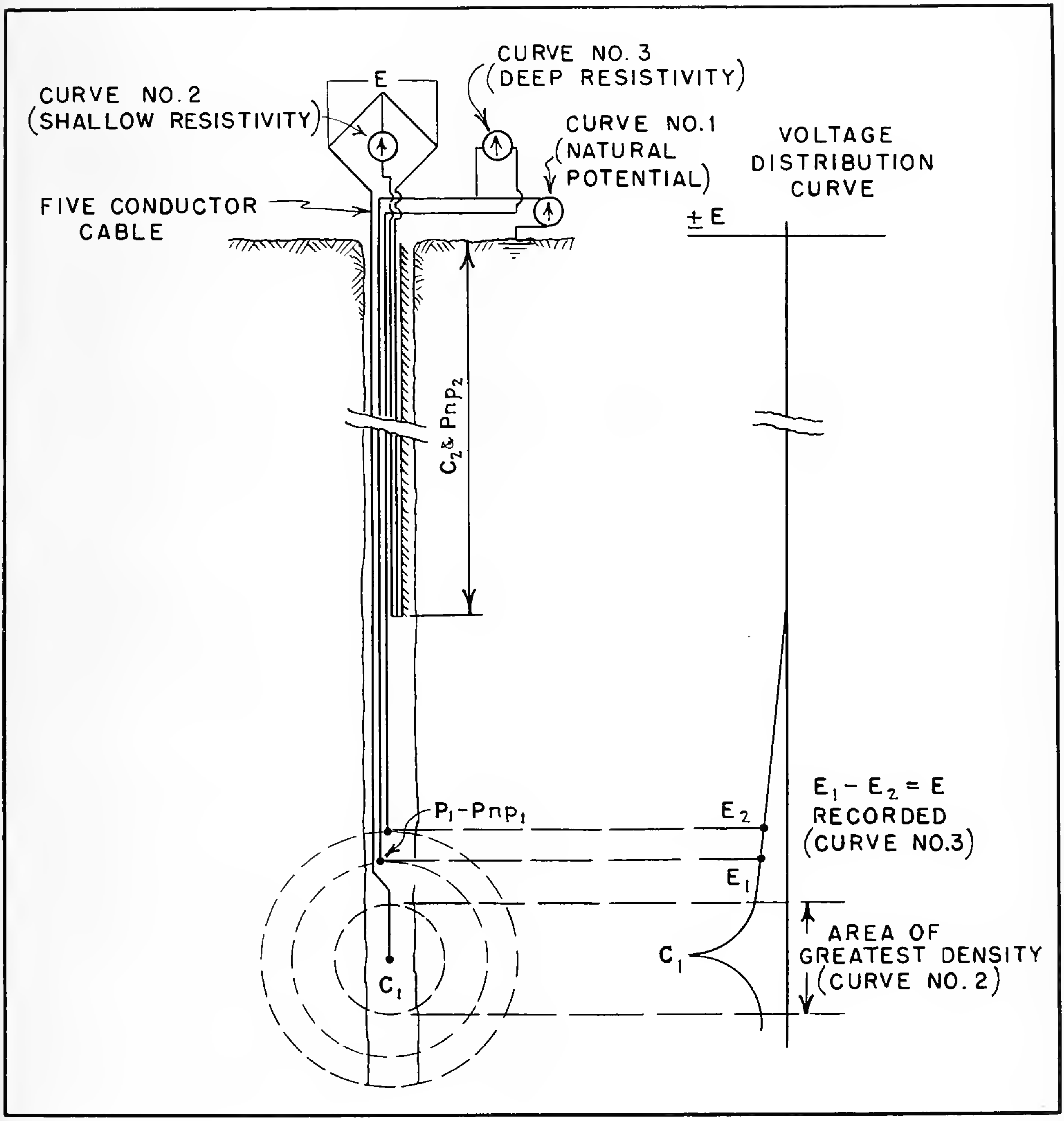

Fig. 9 Diagram Showing the Lane-Wells Company's Method of Obtaining a Composite "Electrolog".

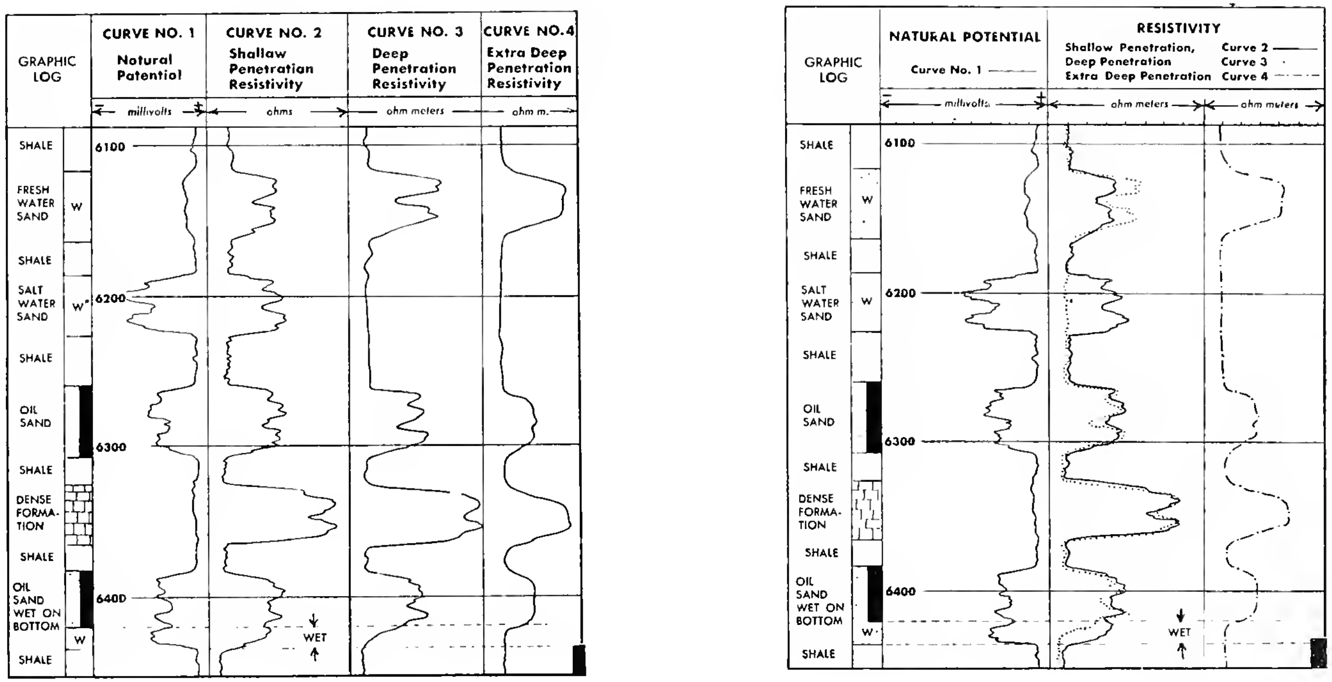

Fig. 10 Two Sets of Composite "Electrolog" Curves and the Corresponding Graphic Logs Showing Stratigraphic Correlations. Drawing taken from Bulletin E-40-1, the Lane-Wells Company, Los Angeles, California, 1940. Page 15.

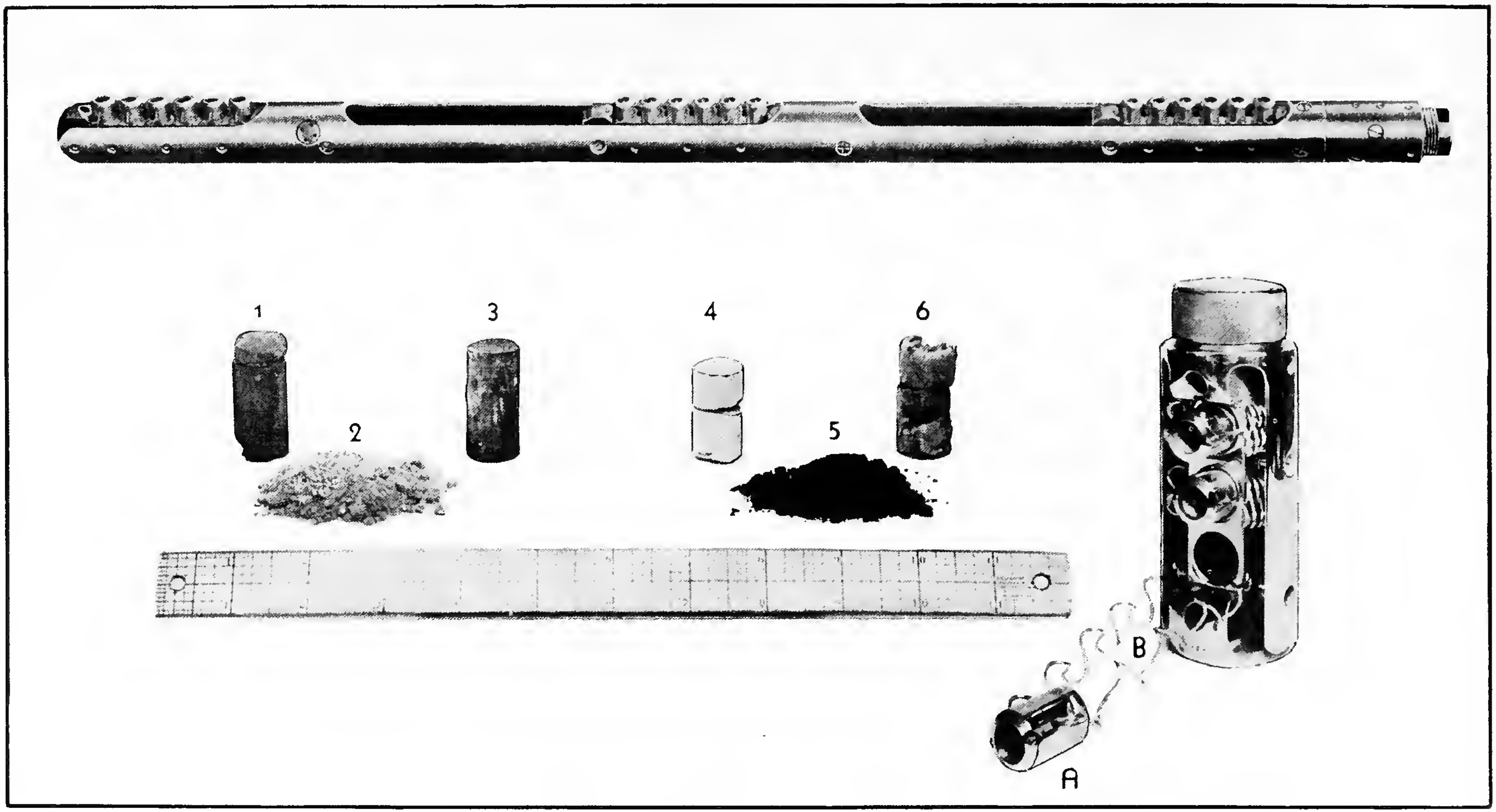

Fig. 11 The Schlumberger Side Wall Sampling Gun. (above) An eighteen bullet gun. (below) Samples and a three bullet magazine. Illustrations taken from a booklet published by the Schlumberger Well Surveying Corporation, Houston, Texas.

Fundamentals of Grouting

Certain fundamental principles in the use of cement grout for sealing wells have been developed by the men who have had considerable success in the field. From their experience may be formulated the following rules which should be applied in every case where grouting is attempted.

1. Know where the grout is going and how it is to be kept there until it sets.

2. Properly prepare the grout mixture.

3. Place the grout in one continuous operation.

4. Always place the grout from the bottom and fill the space upward.

5. Conversely never pour cement down into the space to be filled.

The first of these principles amounts to no more than knowing what is actually happening during the grouting operation. Satisfactory techniquesfor grouting wells have been designed to provide this knowledge.

The grout should be prepared using Standard Portland Cement that meets American Society of Testing Materials specifications. A mixture of 4 1/2 to 5 gallons of water per 94 pound bag of cement should be used. Authorities differ as to the permissible upper limit of water cement ratio. Watry 19/ states that 5.5 gallons per bag of cement is the maximum permissible while Hough 20/ gives 7.5 gallons per bag as the upper limit.

A number of admixtures and additives are used to improve pumpability and cohesiveness of cement grout or to reduce loss into permeable formations. These are: 21/

19/ "Methods of Cement Grouting for Sanitary Protection of Wells" The Wisconsin State Board of Health, Madison, Wisconsin, July, 1938.

20/ J. F. Hough, C. E. "Cementing Water Wells", Typewritten Manuscript, Undated.

21/ "Substitute Casing Materials for War Emergency Well Construction" The Wisconsin State Board of Health, Second Edition Revised, June, 1943. p. 14

Hydrated Lime. The addition of three to five per cent by weight of hydrated lime is claimed to improve pumpability without detrimental effect on hardening.

Aquagel. A gel-forming clay used in oil well construction. Added to Portland cement it reduces shrinkage, improves pumpability and reduces both the loss of grout and the amount of cement required to produce a given column of grout. It is a product of the National Lead Company, Baroid Sales Division, Tulsa, Oklahoma.

Puzzolith. A cement dispersing agent. It increases pumpability, reduces shrinkage, prevents clumping or segregation and increases the strength of the hardened grout. It is a product of the Master Builders Company, 7016 Euclid Avenue, Cleveland, Ohio.

Jellflake. Mica flakes used in oil well construction to reduce loss of drilling mud or the loss of grout in permeable formations. A product of Dowell Incorporated, Kennedy Building, Tulsa, Oklahoma.

Cellulose Flakes. Cellophane flakes used to reduce loss of grout or mud into permeable formations. A product of the Du Pont Company.

The grout should be prepared so that a supply of fresh material is constantly on hand and the grout should be placed as soon as possible after mixing to avoid premature setting. The mixing must proceed at about the rate of placing. For small jobs the grout may be mixed by hand in steel barrels. Four sacks of cement are sifted into 20 gallons of water while stirring vigorously with a suitable paddle. The rate of grouting determines the number of mixing barrels needed.

Any small concrete mixer may be used and can be adapted to grout mixing by closing the clearances back of the mixer blades and fixing splash plates at the discharge chute. Special power driven grout mixers are available. One of the most satisfactory mixers is the jet type shown in Figure 12. The jets are adjusted on the basis of trial to give the best results and cement is fed into the hopper at a uniform rate to give a water cement ratio of about 5 gallons per bag of cement. The cement grout in the storage vat should be agitated continuously to prevent settling of the cement particles.

A double acting flexible reciprocating pump is the most satisfactory type for placing the grout although any slow speed diaphram or piston water pump of adequate capacity and working pressure range can be used. Most well drilling equipment and concrete handing concerns furnish grout pumps. In no case should gravity feed be depended on in placing grout.

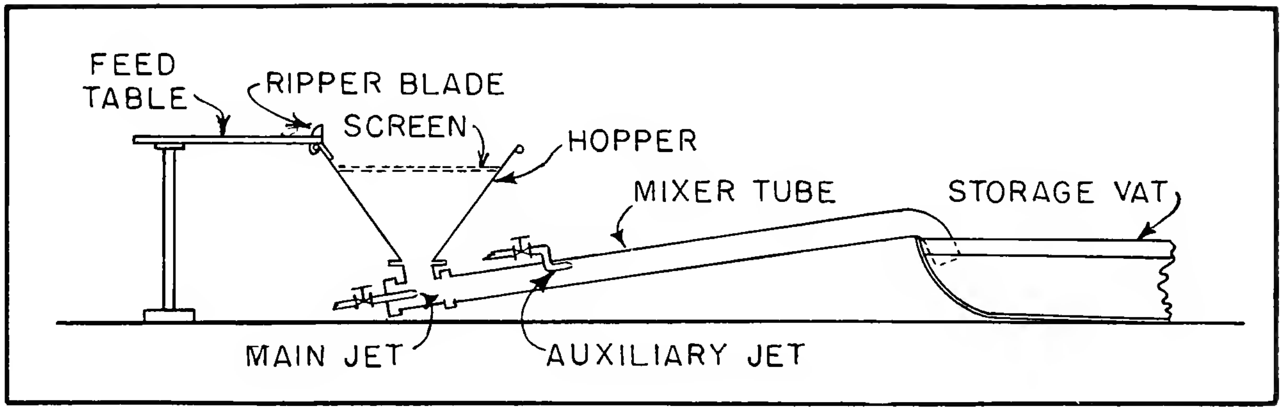

Fig. 12 Jet Type Mixer. Drawing from "Methods of Cement Grouting for Sanitary Protection of Wells". Wisconsin State Board of Health. July 1938.

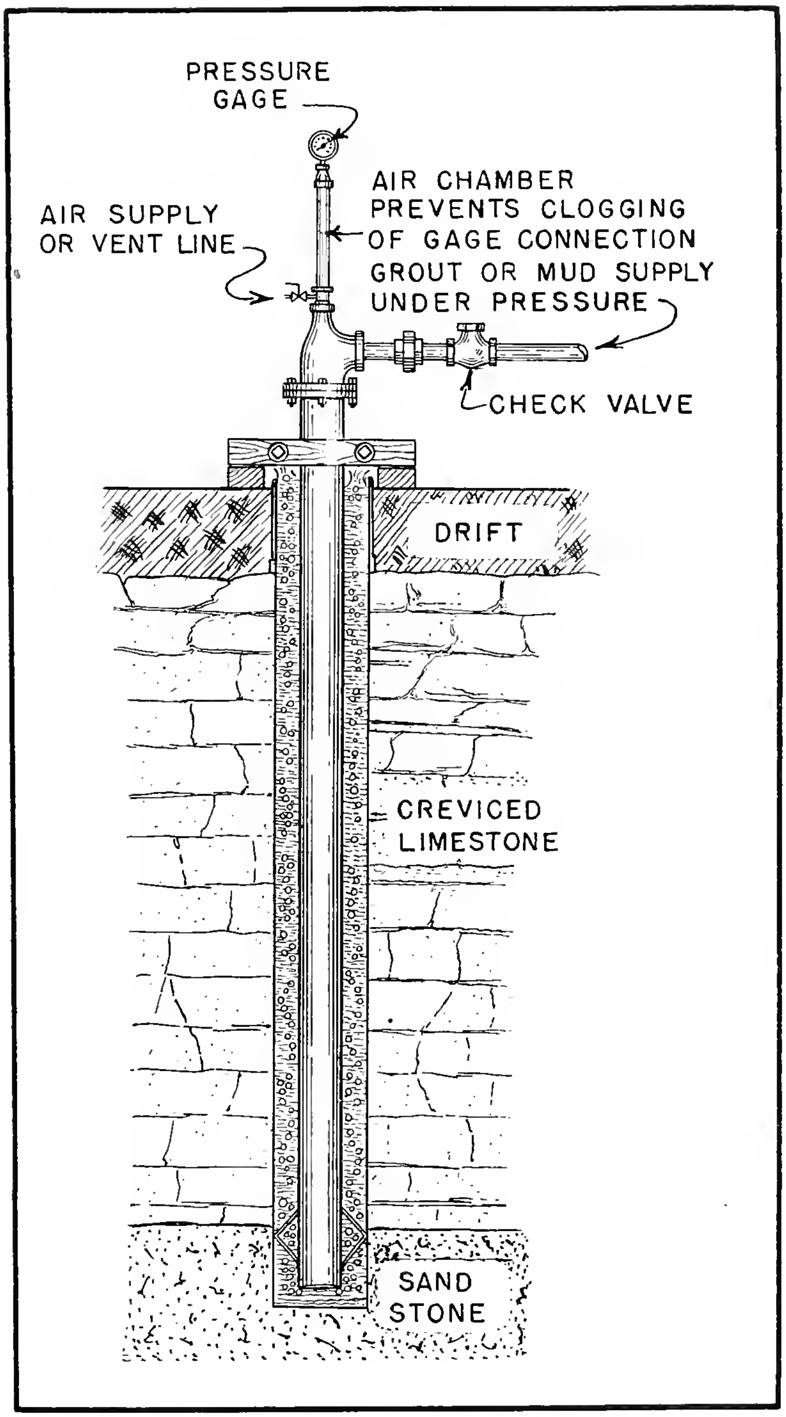

Fig. 13 Showing the set-up for A Capped Casing Method of Grouting that would be difficult to control. Drawing from "Grouting Under Water", by Louis T. Watry, The Driller, Vol. 11, No. 1, p. 9. January 1937.

Since cement grout is much heavier than both water and drilling mud it must be placed at the bottom of the space to be filled so these fluids and any loose materials such as results from cavings are floated or carried upward ahead of the grout. Allowing grout to be dispersed by attempting to settle it into place through water is almost certain to produce poor results, if not actual loss of most of the grout.

In the following discussions and computations of hydraulic situations encountered in connection with the grouting of new and old wells the weights and pressures given in Table XV will be used.

Grouting New Wells

The various methods that have been used for grouting wells during original construction are described in the order of complexibility of set-up required. Appropriate descriptive titles based on the distinguishing features have been given each method. These are: (1) Simple outside casing grouting; (2) plug and foot valve methods: (3) the mud plug method; (4) capped casing methods; (5) the grout piston or Halliburton Oil Well Cementing Company method, and (6) the packer pipe method. It is assumed in all these methods that the hole is stopped in an impervious formation and the casing cemented in place before drilling into the aquifer. The Halliburton Oil Well Cementing Company, Duncan, Oklahoma, has developed many special devices and methods for cementing wells, among which is a method they call "Full Hole Cementing" by which rotary drilled wells can be carried to the full depth with a screen mounted on the casing before the cementing operation is started.

TABLE XV

WEIGHTS AND PRESSURES OF WELL FLUIDS

	Weight lb/cu. ft.	Feet Head to exert 1 lb/sq. in	lb/sq. in per Foot Head
Fresh Water	62.4	2.31	0.433
Drilling Mud 37% Clay by Weight	80	1.80	0.555
Grout 5 Gallons Water per bag of Cement	123	1.17	0.857
Fine Water Saturated Sand 40% Porosity	124	1.16	0.86

Simple Outside Casing Method.

Perhaps the simplest method used for cementing a casing in place is that of pumping the necessary quantity of grout into the hole and then inserting the casing with a plug in the lower end to force the grout to rise in the annular space as the casing descends. This method is not recommended by Hough 20/ probably because the casing must be strung and sent down the well before the grout has had time to take its initial set. In relatively shallow wells this should not be difficult for grout will remain fluid for at least two or three hours after mixing. Caving of the formations as the casing is run in would also cause difficulty with this method.

The following calculations should be made to determine the weight necessary to force the casing down.

Assume 10" standard casing is to be cemented into a 14" hole 100 feet deep. The quantity of grout used should be about 25 per cent in excess of the amount necessary to fill the annular space in order to allow for flushing and for taking of grout by fractures or coarse formations. The quantity of grout needed is:

$$\frac{\pi\ 7^2 - 5^2}{144} \times 100 \times 1.25 = 65.5 \text{ cu. ft.}$$

or 490 gallons

This amount should be pumped through a 2" grout pipe into the bottom of the well as rapidly as possible and the casing inserted immediately.

Standard 10" casing weighs 32.75 pounds per foot length including couplings and is 10.192 inches ID and 10.75 inches O.D. The bouyant force on the casing when surrounded by grout is the weight of the grout displaced or

$$\frac{\pi\ \overline{10.75}^2}{4 \times 144} \times 123 \times 100 = 7,770 \text{ lbs.}$$

The weight of the casing is

$$32.75 \times 100 = 3,275 \text{ lbs.}$$

Therefore there must be exerted a minimum additional vertical force on the casing of

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20/ J. F. Hough, C.E. "Cementing Water Wells", typewritten manuscript, Undated.

$$7700 = 3270 = 4500 \text{ pounds.}$$

Filling the casing with water will add

$$\frac{\pi \; \overline{10.2}^{2}}{4 \times 144} \times 62.4 \times 100 = 3540 \text{ pounds weight}$$

or with drilling mud

$$\frac{\pi \; \overline{10.2}^{2}}{4 \times 144} \times 80 \times 100 = 4500 \text{ pounds weight}$$

Therefore, in this instance the weight of the casing filled with drilling mud would just about balance the bouyant effect of the grout. Considerable additional downward force would be needed to overcome the viscus and wall friction effect before the casing reached the bottom of the hole. The driller should, therefore, be prepared to apply this additional vertical force by use of jacks, weights or tackle. Once in place the casing should stay down. After the grout has been given time to set the plug can be drilled out and the hole continued.

The uncertainty of being able to force the casing to the bottom and the need for speed in setting the casing militate against the use of this method.

A second simple method, Figure 14 a, also not recommended by Hough, is to set the casing centered in the well and driven firmly into the bottom. A grout pipe which under no circumstances should be less than 1 inch diameter is inserted to the bottom of the annular space between the casing and the wall of the hole and the grout is pumped in until it flows free and clean at the surface. In order to prevent a break through into the casing at the lower end it would be advisable to fill the casing with drillers mud or water and cap it at the upper end.

Plug and Foot Valve Method.

This method is shown schematically in Figure 14 b. Into the plug at the lower end of the casing is fitted a short section of grout pipe equipped with a foot valve on the lower end and a left hand thread at the upper. The casing and the rest of the grout pipe are strung into the hole and suspended with the plug a short distance above the bottom. Spacers welded to the casing assist in centering the pipe in the hole. Water or drillers mud should be circulated down the grout pipe and up the annular space to assure freedom from stoppages. The grout is then pumped in until it flows clean at the surface. Calculations of the type mentioned

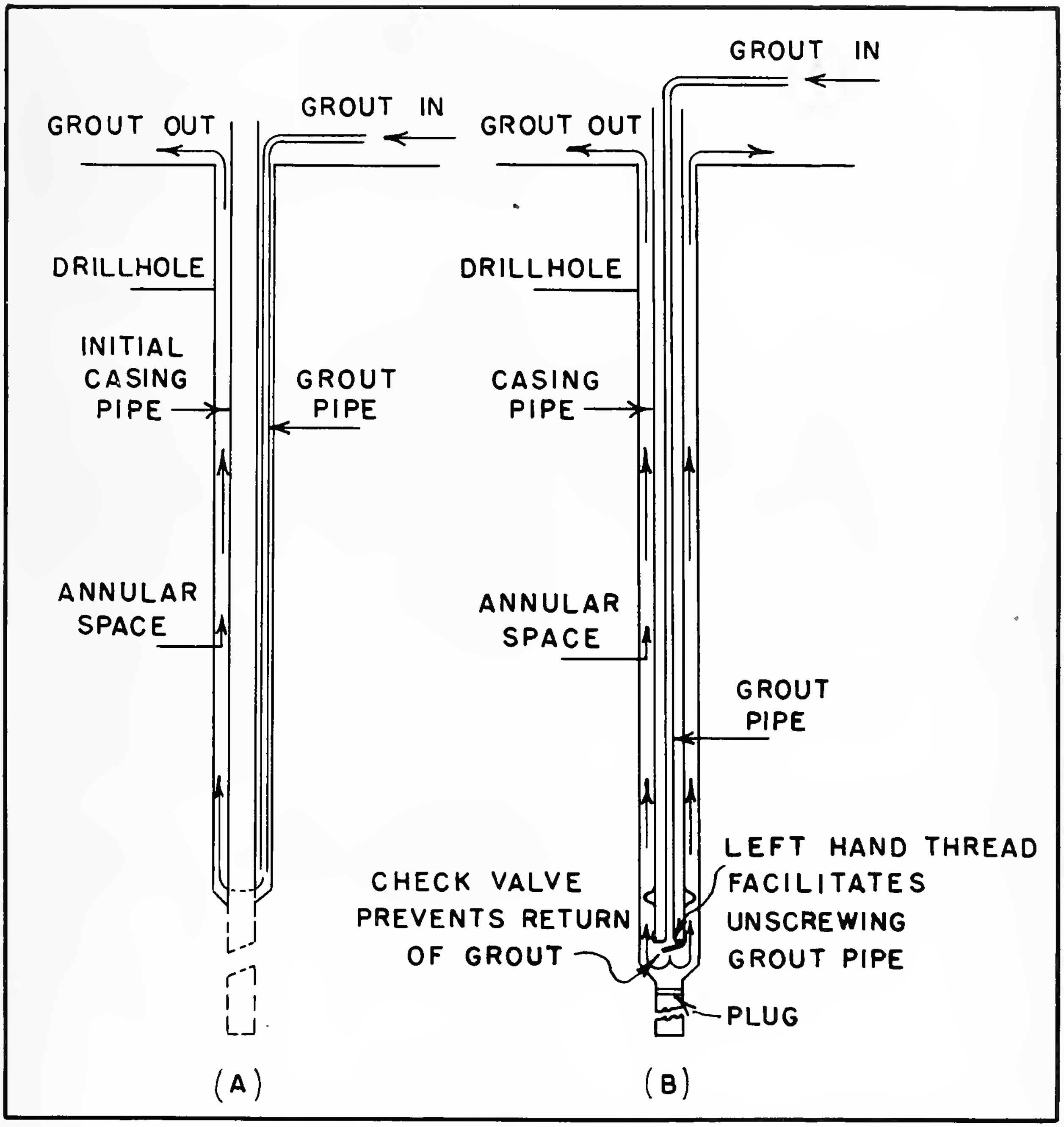

Fig. 14 Two Arrangements for Grouting New Wells.

above show that the casing has to be filled with mud to prevent its rising during the grouting. As soon as grouting is complete the casing is forced to the bottom and the grout pipe unscrewed, the left hand thread assuring it will break at the plug. The grout pipe is then raised a short distance and the pipe and casing thoroughly flushed with water or mud. Three to seven days are allowed for the cement to set after which the plug, the piece of grout pipe and the check valve are drilled out and the well continued on down.

The Mud Plug Method.

The Stevens Southern Company, Jacksonville, Florida, uses a system of cementing that is here called the mud plug method. 22/ For a 12 inch well the rotary rig is used to bore a 17 to 19 inch hole to cap rock. The 12 inch casing is then sunk to a point just off bottom and the drill stem, equipped at the lower end with a loose plug, is run down to the bottom of the casing. The casing is filled with mud and the grout is then pumped in until the annular space is filled. If the mud tends to rise in the casing which it would do if the entire length of the casing is to be grouted, a cap is welded on the casing to hold the mud down. When the cementing is finished the casing is driven down into the cap rock to embed the shoe in both rock and cement, and the drill stem is removed. Cable tools are used to drill out the cement in the bottom of the hole and continue the well into rock.

The Capped Casing Methods.

Two methods depending on the handling of air, water and grout through a capped casing have been used. The first which is described by Watry 23/ seems to have several disadvantages that are avoided in the procedure described by Hough. 20/

Figure 13, page 89, shows the set-up for the first method.

22/ L. H. Houck, "Millions of Gallons". The Driller, Vol. 15, No. 12, p. 4, December 1941.

23/ Louis T. Watry, "Grouting Under Water". The Driller, Vol. 11, No. 1, p. 8, January 1937.

20/ J. F. Hough, C.E. "Cementing Water Wells", typewritten manuscript, undated.

An air and a grout or mud line are attached to the capped casing and a gage is used to determine the location of the water, grout, and driller's mud in the well. Air is first blown into the casing until it is free of water. The air line is then closed and grout is pumped into the empty casing and falls to the bottom partially filling the casing and rising outside in the annular space. After the desired amount of grout has been pumped into the well, mud is pumped until the casing is filled. As mud is pumped in, air is vented from the casing to hold the grout at the desired level.

As the grout column rises in the annular space the air inside the casing will be compressed permitting the grout to partially fill the casing. Computations shown in Appendix IX, page 221, indicate that the grout would rise 32 feet inside a 100 foot casing. In order to prevent this the air pressure would have to be raised gradually as the grout is pumped. This operation would be very difficult to control. Final replacing of the air with mud or water without disturbing the grout would be even more difficult. About the only practical means of accomplishing the latter operation successfully would be to observe the grout level in the annular space and to vent the air at a rate sufficient to keep the grout from rising as the mud is pumped inside the casing. This method of grouting is therefore not recommended.

A much more practical scheme has been worked out by Hough. 20/ Figure 15 shows the well set up. A 2-inch diameter grout tube is run inside the casing to a point above the bottom of the casing which in turn is suspended off the bottom of the hole. The grout tube comes out through a pressure tight swedge nipple that closes the upper end of the casing. Water or mud and grout lines are connected to the grout tube and a vent line is tapped into the swedge nipple. Water is first pumped down the tube and out through the annular opening to flush extraneous material from the space to be grouted. Water should be allowed to fill the casing during this operation. With the vent line closed grout is then pumped down the tube until it flows freely at the surface. The casing is then forced to the bottom of the well. The casing vent line is opened and the grout in the tubing and inside the casing is flushed out with water. All valves should then be left tight until the cement has set in order to prevent a break through at the lower end of the casing.

Advantages of this method are its simplicity, the complete control of operations at all times, and the fact that no plugs

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20/ J. F. Hough, C.E. "Cementing Water Wells", typewritten manuscript, undated.

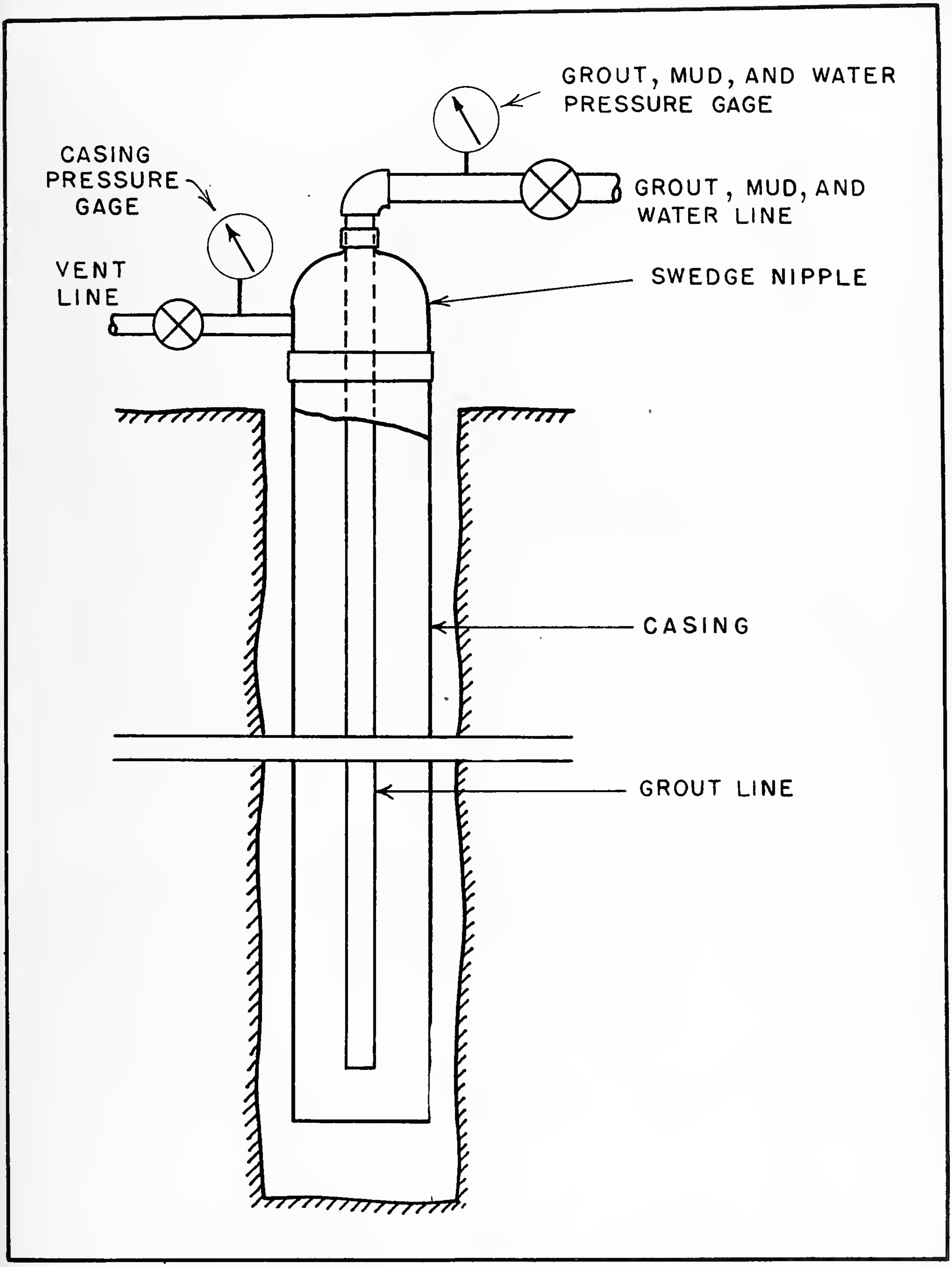

Fig. 15 Set-up for a Satisfactory Capped Casing Method of Cement Grouting a Well.

or other obstructions need to be drilled out after the grouting job is finished.

Grout Piston or Halliburton Oil Well Cementing Company Method.

The Halliburton Oil Well Cementing Company has developed highly successful grouting techniques designed primarily for sealing oil wells where the techniques used for water wells would require either too much time or too much pressure for successful application. Wells can be grouted by the Halliburton method either in single or multiple stages. The arrangement for two stage grouting is shown in Figure 16. With the casing and annular space full of drilling mud a capped section of pipe containing the four grouting plugs is attached. There are mud and grout connections to this section above each of the four plugs and a log cable leading in through the cap. The amount of grout required to fill the annular space of the first stage is carefully measured in between plugs 1 and 2. A sufficient quantity of mud is then pumped in between plugs 2 and 3 to almost completely fill the lower stage casing, thus forcing down the plugs 1 and 2 and the piston of grout between them. Grout for the upper stage is next pumped in between plugs 3 and 4 and finally more mud to force down plug number 4. In moving down, the first and second plugs clear the tapered restriction on the sleeve valve for the upper stage and when plug 1 seats on the float valve */ the grout is squeezed past it and through the guide shoe into the annular space. The third plug should seat on the sleeve valve at the lower end of the upper stage and push it open when the second plug is a few feet above the first. All plugs, the float valve, the guide shoe and any grout inside the casing are drilled out after the cement has set.

Barring accidents the only difficulty that might be anticipated using the Halliburton method is that the excess weight of the grout traveling down inside the casing might create a vacuum sufficient to break the liquid column at the casing head. Ability to supply grout very rapidly should overcome the difficulty. Moreover, when the grout begins to enter the annular space the pump pressure may rise suddenly so that equipment able to withstand rapid pressure increases must be used.

Packer Pipe Method.

The packer pipe method has been developed to grout short liner pipes in the lower portion of a well. Figures 17, 18, 19 and

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*/ Float valves are used in lowering long strings of casing in to deep oil wells to take the strain off the casing. A string of casing 5000 to 10,000 feet in length is a tremendous weight to suspend from its upper end. The float valve utilized the natural bouyancy of the casing so that it may be floated down.

and 20 show the set-up and details of the check valve and packer arrangements. The lower end of the liner pipe is fitted with a drillable plug and check valve to which the grout pipe is attached by a right and left coupling. Grout escape holes are drilled in the top of the liner as indicated in Figure 18. When the last joint of liner is strung, the packer assembly shown in Figure 19 is set on top the liner and packer pipe is strung. The whole weight of grout pipe, liner, packer and packer pipe must be carried by the grout pipe during the stringing. When the liner has seated on the bottom of the well the packer pipe is forced down and the soft rubber gland closes the space between the packer pipe and the upper string of casing. Water is first circulated down the grout pipe, up the annular space to the top of the liner and out through the packer pipe in order to clear the space to be grouted. Grout is then pumped until it flows freely at the surface. The grout pipe is broken at the right-left coupling near the bottom of the well, is raised slightly and the liner and packer pipe flushed with clean water. The grout is allowed time to take its initial set, usually five or six hours and the grout line and packer pipe are then removed. The liner will almost certainly float if the packer pipe is removed before the grout sets.

Computations of the maximum bouyant forces which exist during the grouting and flushing operation is shown in Appendix IX, page 221, for a typical situation. In the example used the net bouyant force is upward showing that the packer pipe must be anchored down securely or liner will not stay in place. Computations also show that a liner pipe 200 feet or more in length is too heavy to be lowered on the grout line.

Figure 22 shows a packer arrangement that can be used when it is considered desirable to use the packer pipe to lower the liner and grout pipe into the well. The packer pipe is extended into the liner pipe and fastened to it by copper or brass cap screws. When the liner is bottomed these screws are sheared off by sharp blows with the tools on the upper end of the packer pipe. The weight of the packer pipe then compresses the packing gland and the flushing and grouting operations may proceed.

The various methods of grouting described above should give the owner and the well driller an idea of the variety of schemes that may be used to cement new wells. No doubt other methods designed to suit particular conditions can be worked out.

In the application of all grouting methods the following fundamental rules and precautions should be adhered to.

1. Plan the work carefully so that every step in the operation can be carried through without interruption. Be sure that the casing is securely anchored down. Be prepared for all forseeable

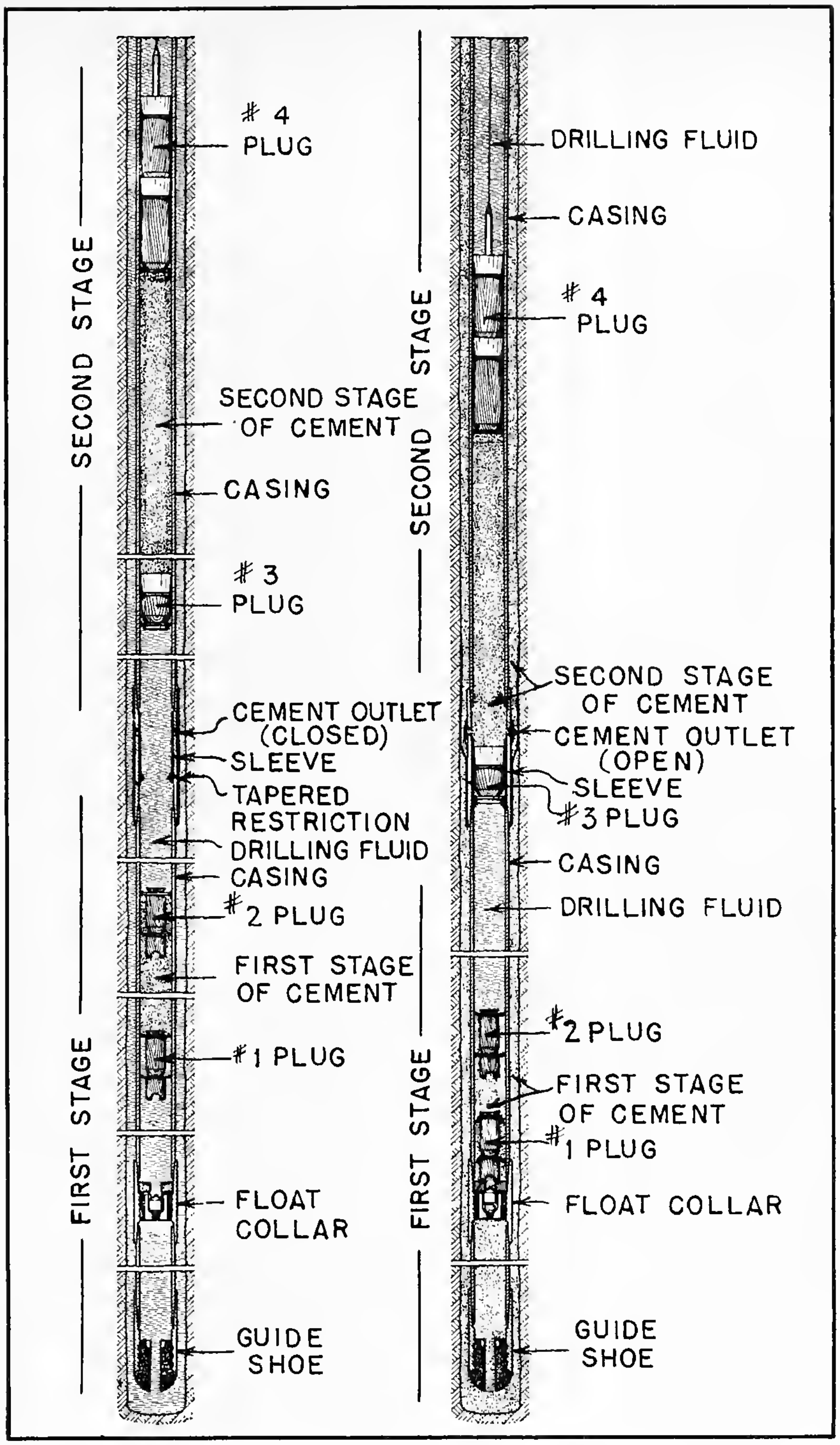

Fig. 1 shows the multiple stage device in the string of casing and two stages of cement slurry going downward through the casing. The lower stage has passed through the multiple stage cementing device without opening the cementing ports.

Fig. 2 shows the first stage of cement in place behind the lower part of the casing; the No. 3 cementing plug, located just ahead of the second stage of cement, has reached the device and forced the sleeve downward, uncovering the cementing ports and allowing the cement slurry to pass out into the space behind the casing above the device.

Fig. 16 The Halliburton Method of Cement Grouting Oil Wells. Drawings taken from Catalogue No. 13. Halliburton Oil Well Cementing Company, Duncan, Oklahoma. January 1942.

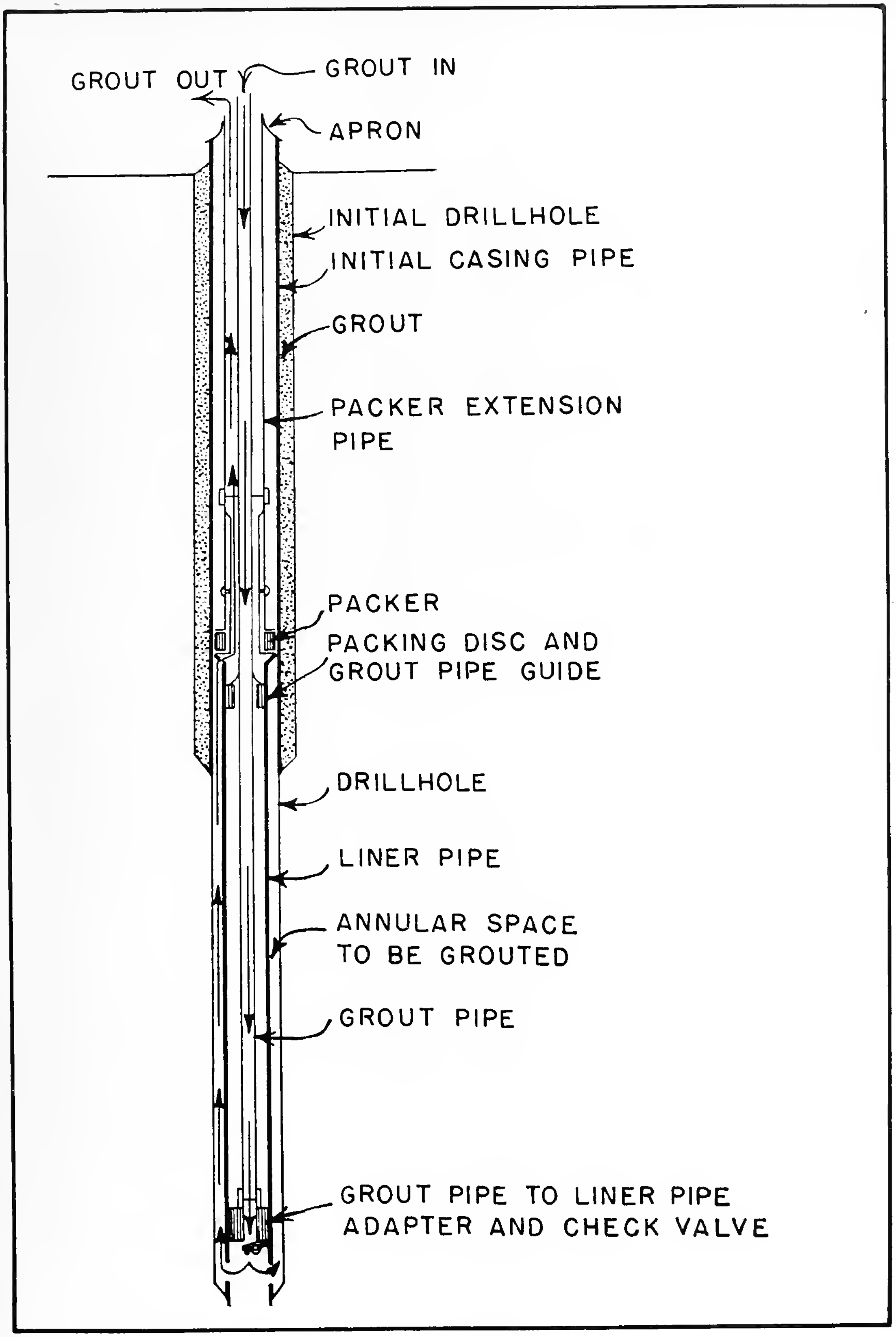

Fig. 17 Set-up for Packer Pipe Method of Grouting. Drawing from "Methods of Cement Grouting for Sanitary Protection of Wells". Wisconsin State Board of Health. July 1938.

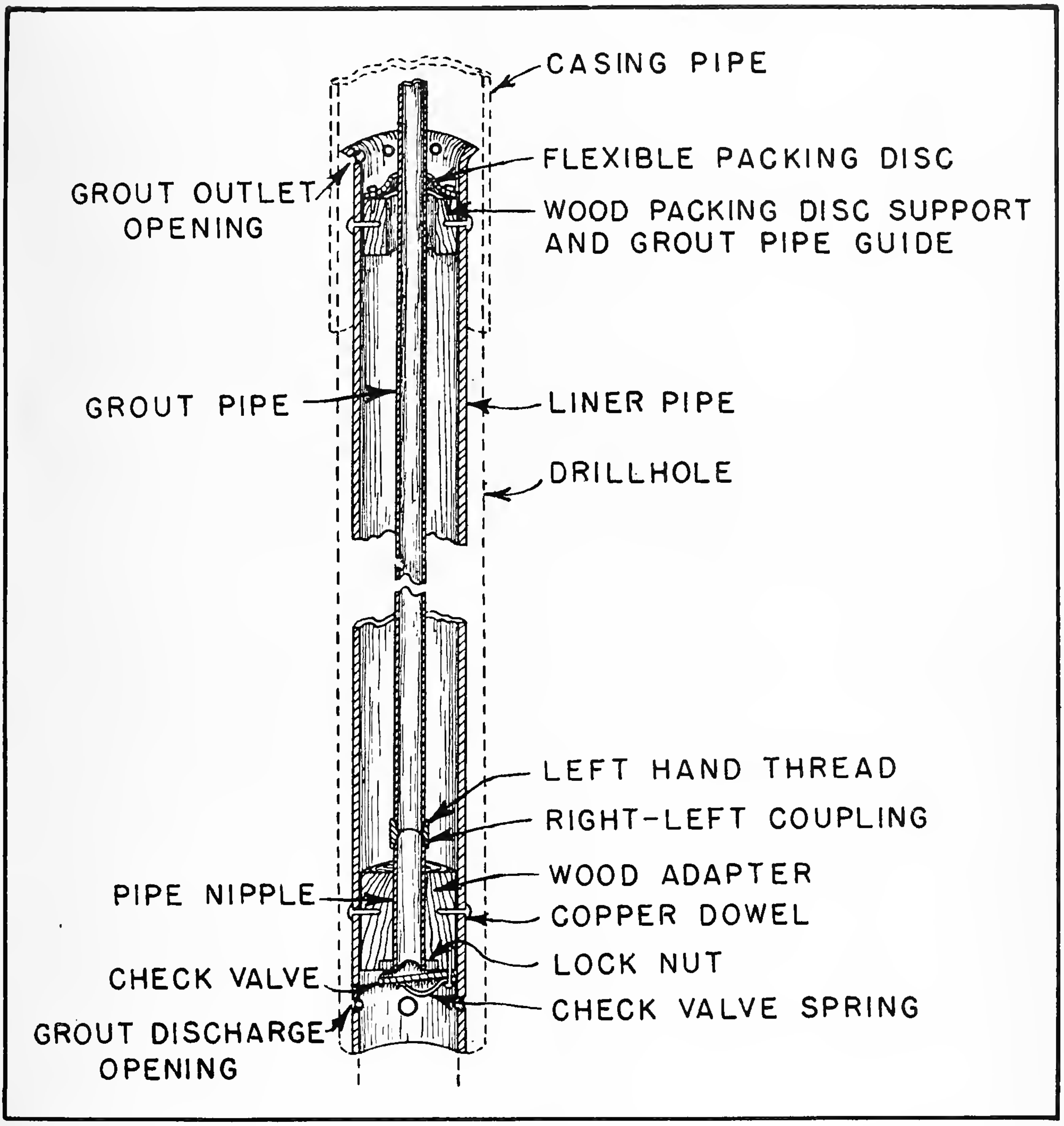

Fig. 18 Detail Showing Arrangement of Grout and Liner Pipe.

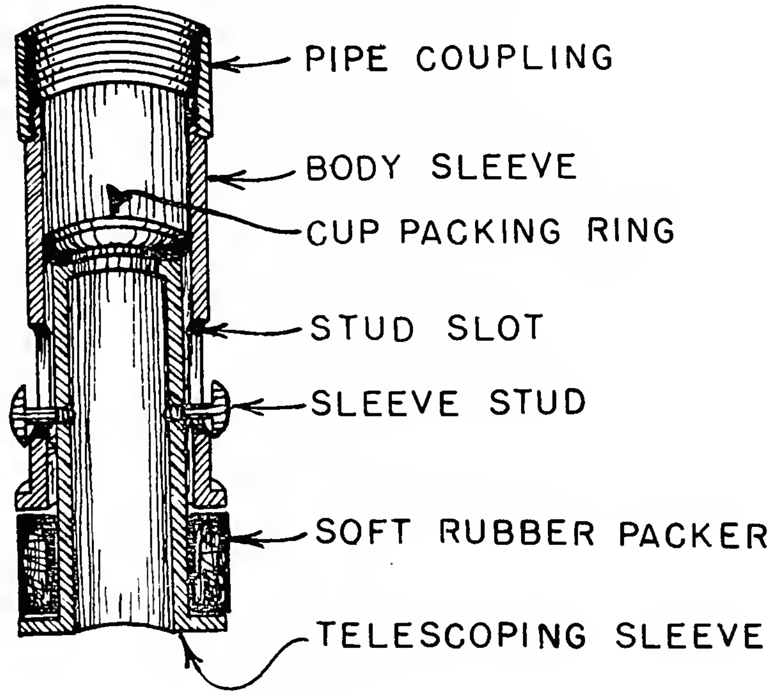

Fig. 19 Detail of Packer Assembly for Use in Connection with a Short Liner Pipe.

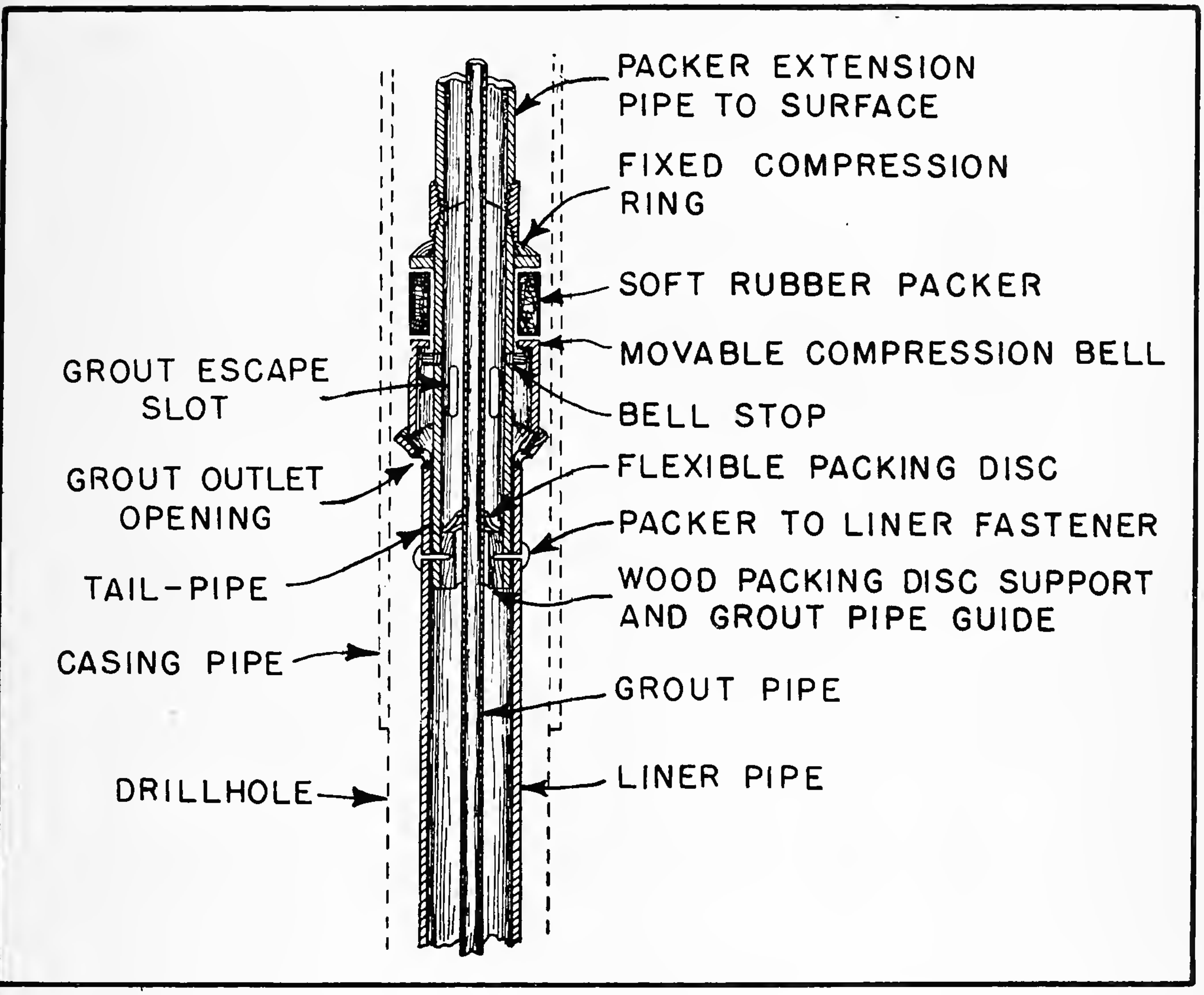

Fig. 20 Detail of Packer Assembly for Setting a Heavy Liner Pipe.

contingencies.

2. Use clean fresh water in a ratio of not more than 5 1/2 gallons per sack of cement to prepare the grout.

3. Grout pipes and the spaces to be grouted should be large enough to permit easy flow of the grout. One inch diameter or width of opening is the absolute minimum that should be used and two inches is the preferred minimum.

4. Mix and pump the grout continuously and always place it from the bottom forcing it to rise into the space to be grouted.

These fundamentals apply equally well to all schemes for repairing old wells and sealing abandoned wells. However, in the latter cases each new situation will call for a good deal more ingenuity than is required for grouting wells during construction.

Repair of Leaking Wells.

Before undertaking the repair of wells in which leakage is known to be the cause of contamination, every reasonable test that might throw light on the underground situation should be made. Tests for diagnosis of the source and cause of salt contamination have been discussed in Section IV. When plans are being formulated for repair operations additional testing is economically justified. If possible information should be obtained as to the hydraulic conditions underground and also concerning the location and magnitude of cavities to be filled with grout.

If a correct picture is obtained of the leaks in the well and of the location of openings around the well a successful grouting program should not be difficult to plan. One of the basic principles of repair work should be to remove all the pumping equipment and as much of the casing as possible from the well and to carry out the work as nearly as is possible according to the methods used for grouting new wells.

Since cement grout will not penetrate fine sand, this material can be used as an effective plug to keep the grout out of the fresh water aquifers at the bottom of the well. With the proper use of fine sand, grout and the necessary tools and equipment, the repair of leaky wells should present no unusual difficulties.

Testing Equipment and Tools.

Perhaps the most valuable piece of equipment that could be designed for preliminary testing of wells is a double packer plug which can be easily set and released and that has a pipe connection to the space between the packers. This can be used in many ways for

pumping in liquids and testing static levels. The Halliburton Oil Company has developed a packer of this type which it uses for testing and for squeeze cementing. The process called squeeze cementing is simply the grouting off of undesirable formations above the bottom of oil wells. This is exactly the objective sought in repairing leaky water wells. Another type of double packer plug which is suggested as practical for shallow work is illustrated in Figure 21. The packers are expanded by applying air pressure higher than the static pressure in the well at the point where the plug is to be set. The double plugs can be made up with any desired spacing. A device of this type can be used for the following things: (1) to pressure test the casing, (2) to accurately locate casing leaks, (3) to estimate the size of leaks, (4) to pump in test fluids at any point along the casing, (5) to determine the static pressure in the various aquifers down the well, and (6) under certain conditions for injecting grout through the casing at any desired point along the well. The principal disadvantage of the air expanded type of plug would be the danger of its bursting or cutting if it happened to be expanded at a point where there was a large hole in the casing.

To pressure test the casing the plugs are made up at any desired spacing and the well is traversed applying fluid pressure to test each section. Leaks would be shown immediately by the lack of sudden pressure rise or by failure of a section to hold pressure.

The test pressure used between the packers should never be greater than the air pressure inside the packers, otherwise the air expanded packers will collapse. This requires that the air pressure on the packers be somewhat greater than the pressure at the top of the test line plus the pressure created by the weight of the water column in the test line. For example, if the tester is at 500 feet and if the gage at the top of the line registers 100 lbs per square inch and the line is full of water the minimum air pressure to expand the packers would be:

$$500 \times 0.433 + 100 = 316 \text{ lbs per sq. in.}$$

Once a leak in the casing is discovered it can be accurately located by moving the packer plugs up or down the well in small increments.

It may be possible to obtain some idea of the size of the leak by investigating the rate at which the leak will take water under different pumping pressures and rates. An estimate may be possible due to the fact that the test line losses can be computed, that the losses outside the leak either are apt to be slight or will vary directly as the velocity, while the leak itself unless large will probably function as an orifice through which the head loss will vary as the square of the velocity. In the case of large leaks and free escape of water outside the casing the increase in loss of head would be approximately that estimated for the test line only.

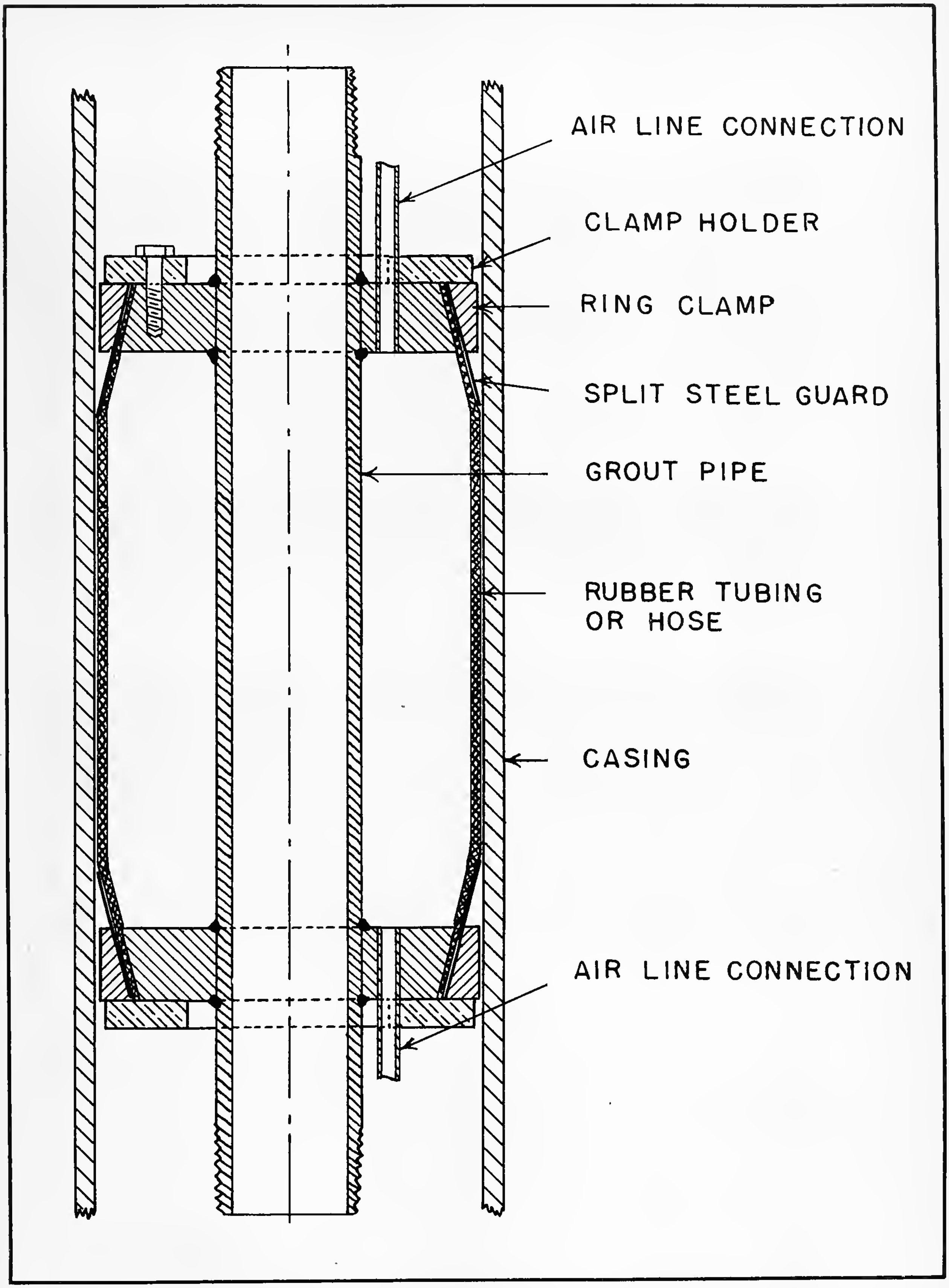

Fig. 21 Sketch of Suggested Air Expanded Packer Plug.

The double packer plug may be used to pump test fluids, either strong salt or dye solutions, into leaks or through especially made perforations to determine leakage along the casing. Heavy concentrations of salt could thus be injected at selected points down a well suspected of leaking and the appearance of salt watched for in nearby wells which are kept in operation. If the salt is leaking down outside the casing of the well tested it should appear in nearby pumped wells in shorter periods as the injections are made through lower perforations. On the other hand, if the salt is traveling laterally through a pervious bed and down the well in operation, the time for appearance in the pumped well should increase as the point of injection is moved away from the transmitting bed.

Pump testing clean water into perforations located at points where the ground is known to be impervious provides a simple method for determining whether the clay is tight around the casing or whether vertical circulation can take place. Furthermore, if the casing is perforated above the injection point any rapid variation in the pumping rate should be reflected in oscillations of the water level inside the casing if there is vertical connection outside.

With a pressure testing tube inside the packer test pipe, Figure 22, the static pressure in selected aquifers can be tested through casing perforations. This information is exceedingly valuable in determining conditions under which the leakage outside, or for that matter inside the casing is either up or down the well. If free outside vertical circulation is possible the variations in static level at the various points along the casing will be slight and will represent the loss of head as water moves either up or down the channel from one pervious formation to the other. Where circulation does exist the amount of the variation in static level is an excellent indication of the size of the channel, particularly if the normal differences in static levels are known from tests in good wells.

In all the above tests it would be wise to plan the work very carefully and use the fewest possible number of perforations that will give the information needed. It may be that perforations at two levels will show conclusively that the well is leaking outside the casing. It would always be a good policy to pump into each perforation before attempting to use it for measuring static levels in order to assure that it is not blocked by material disturbed when the perforation is made.

The double type packer can also be used to inject cement grout at any desired level. Under some conditions this may be desirable. Two things limit the usefulness of this scheme. First the packers must be removed before the grout has time to set firmly, in which case the outside pressure might force grout back into the well. And second, if there is free circulation outside the casing the grout might be carried away or diffuse into the water in the outside channels,

or might possibly sink to the foot of the well and clog the aquifer that is to be protected.

Unfortunately time and resources were not available to buy or build a double packer plug and carry out these tests on leaking wells. Any investigation of conditions within and around a well depends on the devising of schemes for taking data that are susceptible to accurate interpretation. The only check on the correctness of interpretations of the data collected is in the final success or failure of the repair job.

Further, when an attempted repair fails it is extremely difficult to tell what has happened or whether the failure was due to incorrect analysis of the test data or to faulty technique in the grouting operations. Only a high proportion of successful repair jobs finally indicate that the tests are sound, the interpretations valid and the repair techniques correct.

Repair Operations.

In attacking repair operations the first objective should be to remove all well equipment and casings so the well may be recased and grouted in exactly the same way as a new well. The reason for this is that only by pulling the casing can there be full assurance that the grout will fill all cavities eroded into the wall of the original hole. Several schemes for repair of wells are described below.

Figure 23 shows the probable condition surrounding the casing of a badly leaking well and indicates a suggested method of repair. The first step in repair should be an attempt to lift the casing and screen. If the bottom of the screen has been cemented in place a casing cutter can be used to sever it. If desired the casing may be cut several feet above the screen which is then left in place.

Assuming that the casing can be moved the procedure should be as follows: Lift the casing so that the bottom of the screen or the casing cut is well up in the impervious bed over the aquifer. Run in sand containing both coarse and fine material and work it into the aquifer by use of a plunger or other means until the well is filled to a point at least several feet above the top of the pervious formations, but not up to the bottom of the suspended casing. This operation is the exact reverse of the well development process and is necessary to prevent the grout from entering and clogging the aquifer. A natural sand with an effective size less than 0.3 mm and a uniformity coefficient of 2 to 4 should be satisfactory. A high uniformity coefficient is desirable in order that large particles be available to start the clogging action in case the well has been gravel packed or the aquifer is a coarse gravel. Allowing the sand to settle into the well and the use of a plunger to work the sand into the gravel will bring the fine

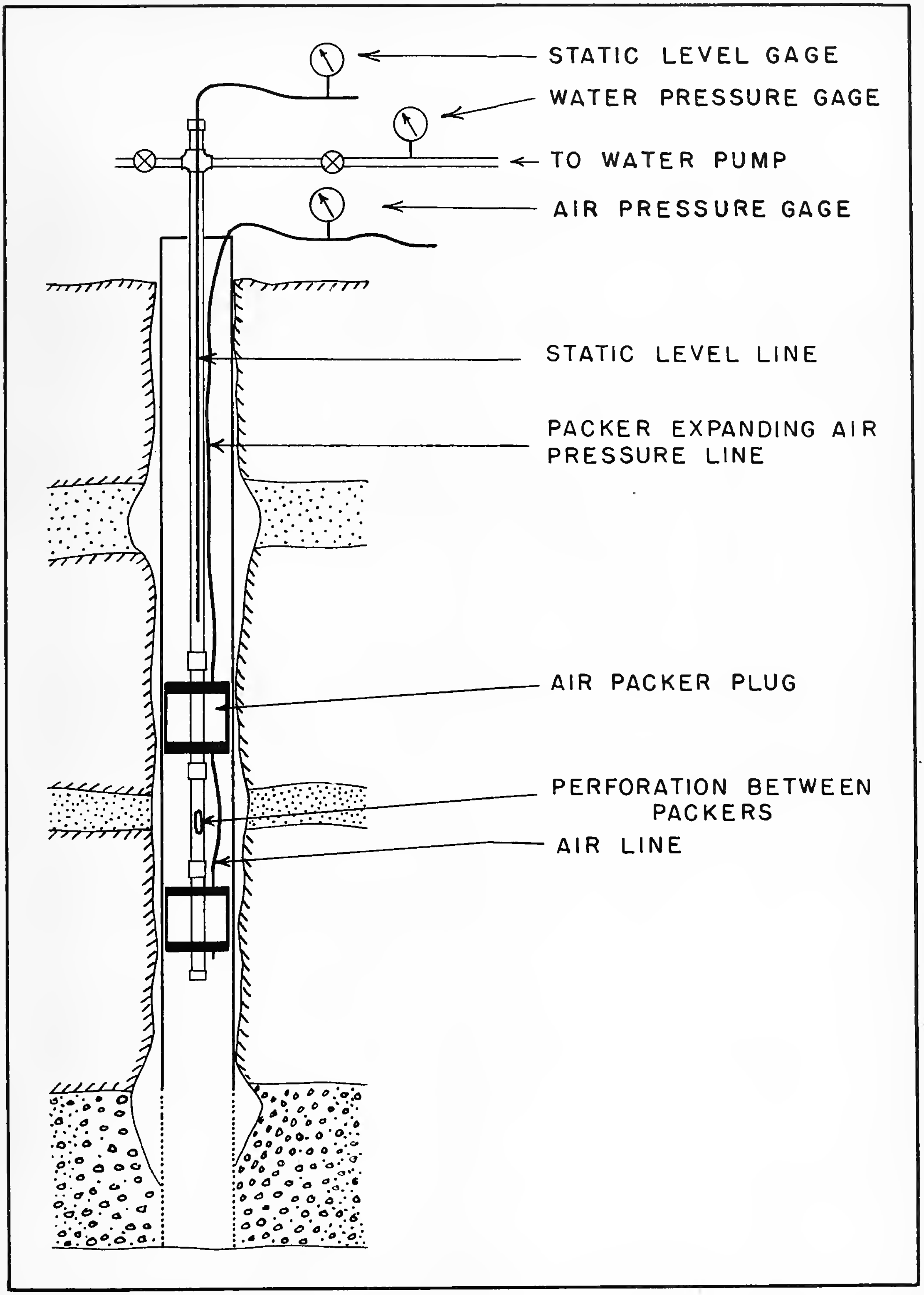

Fig. 22 Arrangement for Using a Double Air Packer Plug to Test a Well.

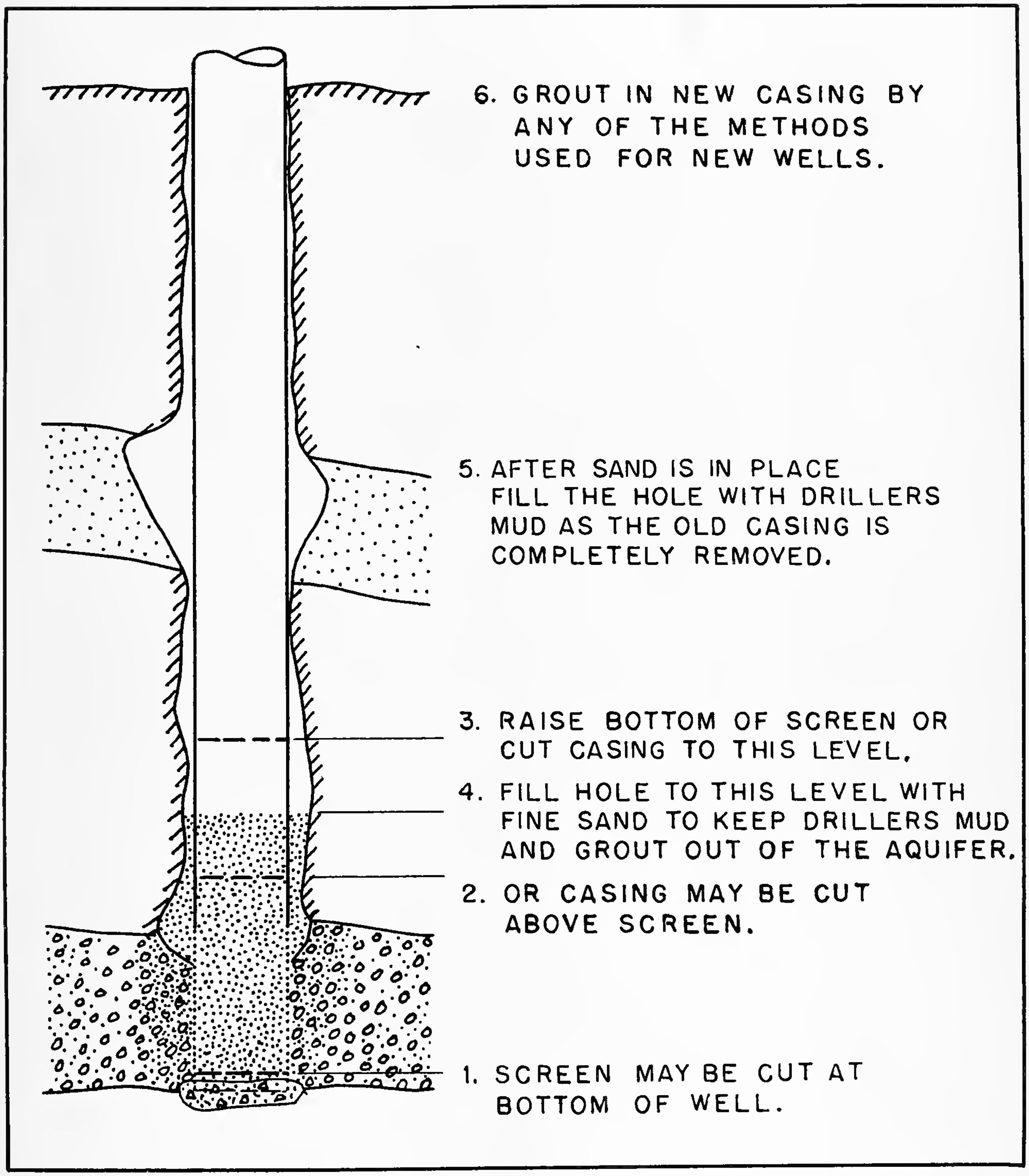

Fig. 23 Suggested Method for Repairing a Leaky Well.

particles to the surface of the sand plug where they are needed to exclude the grout. The sand should be tested above ground to make absolutely sure that neither grout nor the driller's mud used in subsequent operations will penetrate the sand.

When the sand is in place, the well should be filled with driller's mud and the casing completely withdrawn. The mud should be introduced near the bottom of the hole but not close enough to the sand plug to disturb it. As the casing is withdrawn mud should be added as necessary to keep the hole full and all mud placed in the well should be carefully measured. The introduction of driller's mud serves three primary purposes: (1) it prevents caving or collapse of the hole as the casing is pulled; (2) it prevents vertical circulation of water between the aquifers during subsequent grouting operations; and (3) it provides a quantitative measurement that gives an idea of the open capacity of the hole. From the latter information the maximum quantity of grout needed can be figured, or the presence of permeable beds that have a high capacity for absorbing either mud or grout may be discovered. The mud level should be determined periodically as the filling progresses, for from these data and a knowledge of the quantity of mud pumped, the diameter of the hole can be computed, or in the case of high loss of mud the level of escape can be determined. The latter information is indispensable for it tells to what level wells can be successfully grouted and it prevents the uncontrolled pumping of grout away into permeable formations where it may do considerable damage if the higher aquifers are still in use. The procedure described here would prevent occurrences similar to the attempted repair job, where 3750 bags of cement were used to mix a thin grout which in turn was pumped in at the surface between casings. Where all this cement went to no one knows, but its injection had little or no effect on the leakage conditions at the well.

The Halliburton Oil Well Cementing Company uses a caliper for open hole oil well logging which could be used satisfactorily for water well logging. Their charge per well for caliper logging is about $70.00 plus 4 cents per foot for wells under 5000 feet in depth. The caliper is shown in Figure 24.

In Figure 25 are shown the plotted results of caliper logging. The fact that the holes are oversize for a considerable portion of their depths shows the ease with which vertical circulation can take place outside the casing and also indicates the importance of knowing the hole diameter when computing the amount of grout needed to fill the annular space outside the casing. The temperature curve shown in Figure 25 illustrates another test used by the oil industry in connection with grouting. In order to determine the level to which the annular space has been filled with grout advantage is taken of the fact that cement liberates considerable heat when setting. The temperatures plotted were measured in the driller's mud inside the casing four hours after the well was cemented.

The uses of caliper logging in oil well construction are: 24/

1. To determine the volumetric capacity of the portion of the hole to be cemented.

2. To determine the volumetric capacity of the portion of the well in which the gravel is to be placed.

3. To determine the size of the hole as it affects drill stem wobble and fatigue and to develop improved methods of maintaining a uniform diameter hole.

4. To show the effects of shooting upon the hole.

5. To locate the proper places to set packers and thus avoid the many cases where the packer "did not hold" probably because of an enlarged diameter hole.

6. To show the changes in geologic structure which are reflected in the diameter of the hole.

Returning to the procedure for repairing a well, once the casing is removed the depth to the sand plug should be checked to ascertain whether serious caving has occurred. A new casing preferably at least 4 inches less in diameter than the hole can then be run in and cemented in place by any of the methods described in the first part of this section, following all the rules and precautions listed there. Drilling out the grout left in the well, bailing of the sand plug, and redeveloping of the aquifer should put the well into satisfactory operation again.

If there is a zone of free mud loss in the hole it may be possible to grout only up to this point. By injecting mud containing additives such as mica flakes, cellophane flakes or sand into these open formations they might be closed and the grouting continued up the well in stages. The great disadvantage in grouting only the lower portion of a well is that the most highly contaminated and corrosive waters near the surface will still have access to the metal casing and leakage through the casing is sure to develop sooner or later.

Figure 26 shows one method of setting the new casing and grouting the well when the original casing is cut off above the screen. The sand plug should be worked back into the water-bearing formation

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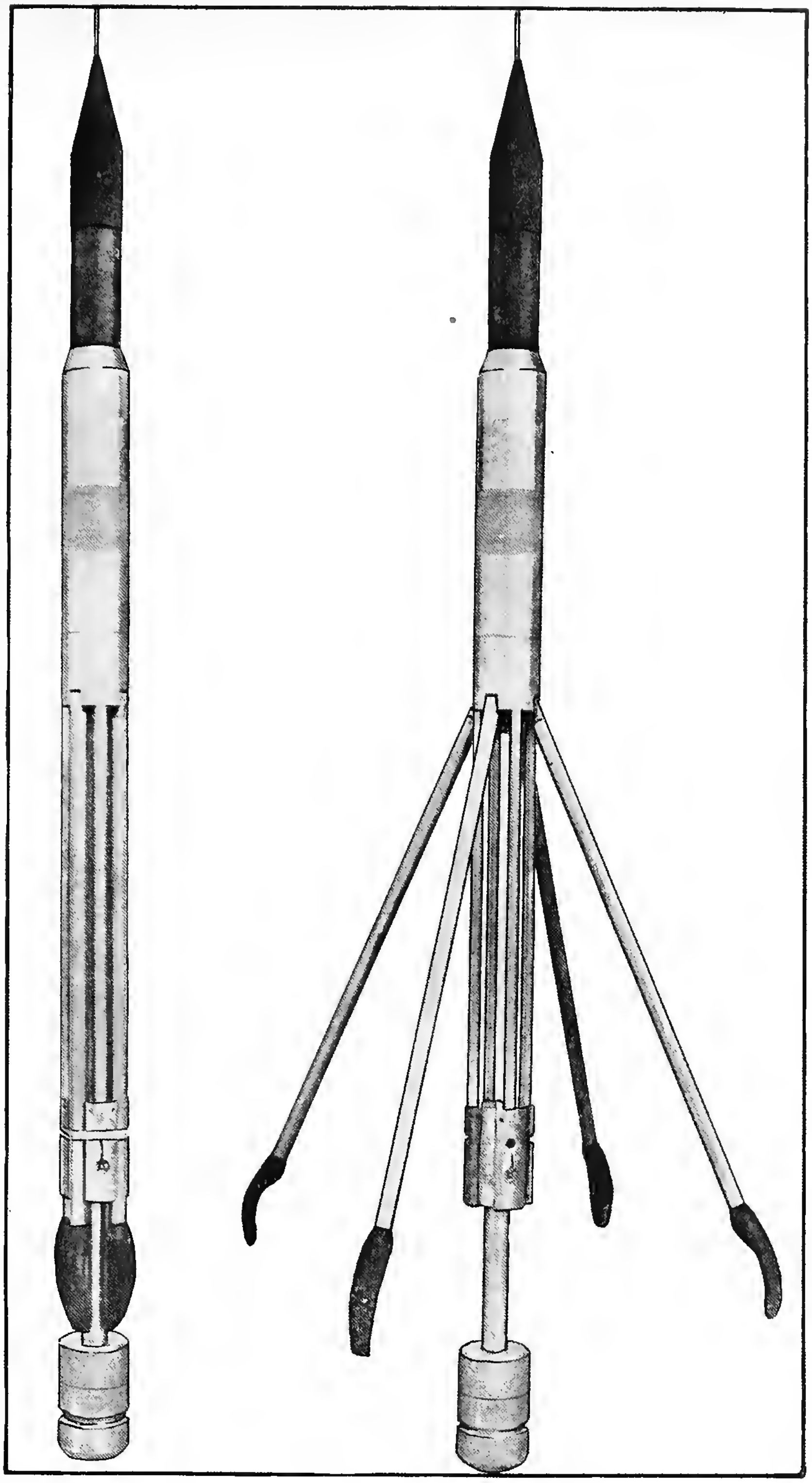
24/ Halliburton Oil Well Cementing Company, Catalogue No. 13, January 1942.



Type of caliper used for open hole logging. Left: Caliper in closed position. Right: Caliper arms released and in position to start logging

Fig. 24 Type of Caliper Used for Open Hole Logging. Illustration from Catalogue No. 13, Halliburton Oil Well Cementing Company, Duncan, Oklahoma. January 1942.

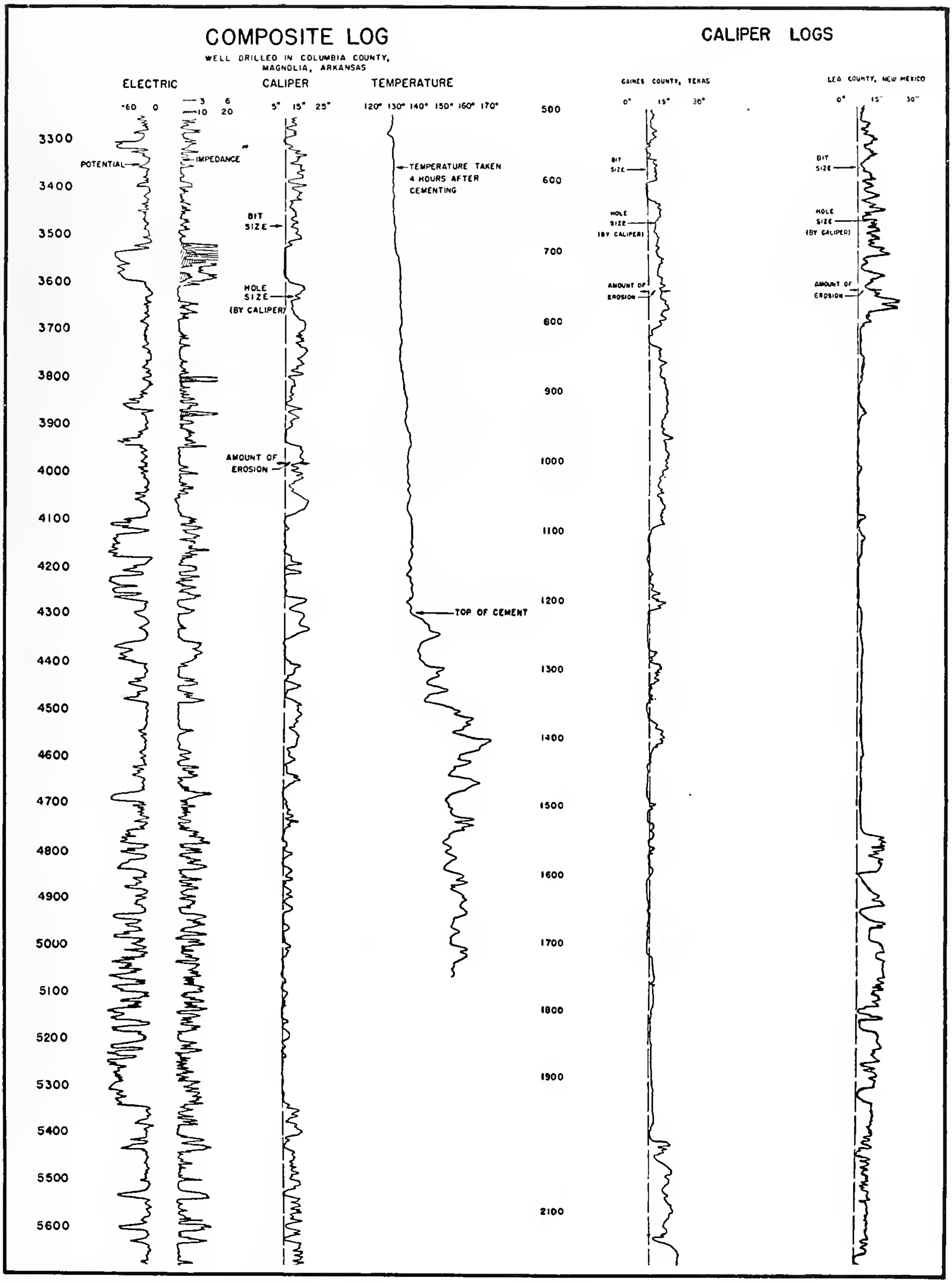


Fig. 25 Caliper, Temperature and Electrical Logging Curves. Drawing from Catalogue No. 13. Halliburton Oil Well Cementing Company, Duncan, Oklahoma. January 1942.

around the screen very carefully to protect it from invasion of grout. In order to be sure that sand is both inside and outside the piece of original casing, the hole should be filled with sand above the cut and the excess down to a point below the casing perforations bailed out before the grouting is started. Sand outside the casing above the grouting perforations can be flushed out with mud or water. After the sand plug is in place the following receipt, which is a modification of the method described by Watry, 25/ may be used with the set-up shown in Figure 26.

1. Three collars, e, 2 inches wide and spaced some 30 inches are built up on the short section of casing, d. These are turned down to form a snug sliding fit inside the piece of original casing which has previously been perforated at b.

2. With the casing in position I and the grout pipe inserted through the capped casing, (as described on page 83) to a point above the sand plug, mud or water is pumped through the openings, B, to flush the annular space.

3. Grout pumping is started and as soon as the lower annular space is filled the casing is lifted to position II so the grout may flow from openings a, as well as b, thus cutting down the resistance.

4. When the grout flows freely at the surface the casing is lowered to position III and the grout line and casing are flushed with mud or water.

If the original casing cannot be removed from the well, the repair job is much less certain to turn out successfully. The old casing should be perforated freely for some distance above the screen in order to assure that the sand used to protect the aquifer from the grout fills the space outside the screen and casing as well as inside. Obviously the sand used must all be fine enough to pass the perforations. Using the capped casing method with an inner tube, page 83, grout can be forced through perforations above the sand plug. However, in order to use the capped casing method successfully the casing must be free of leaks or perforations above those used for grouting.

If the casing is perforated at several points along its length, the use of a removable packer plug through which a grout tube leads to a foot valve provides the most satisfactory arrangement. This could

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25/ Louis Watry "Grouting Procedures". The Driller, Vol. 11, No. 7, p. 8, July 1937.

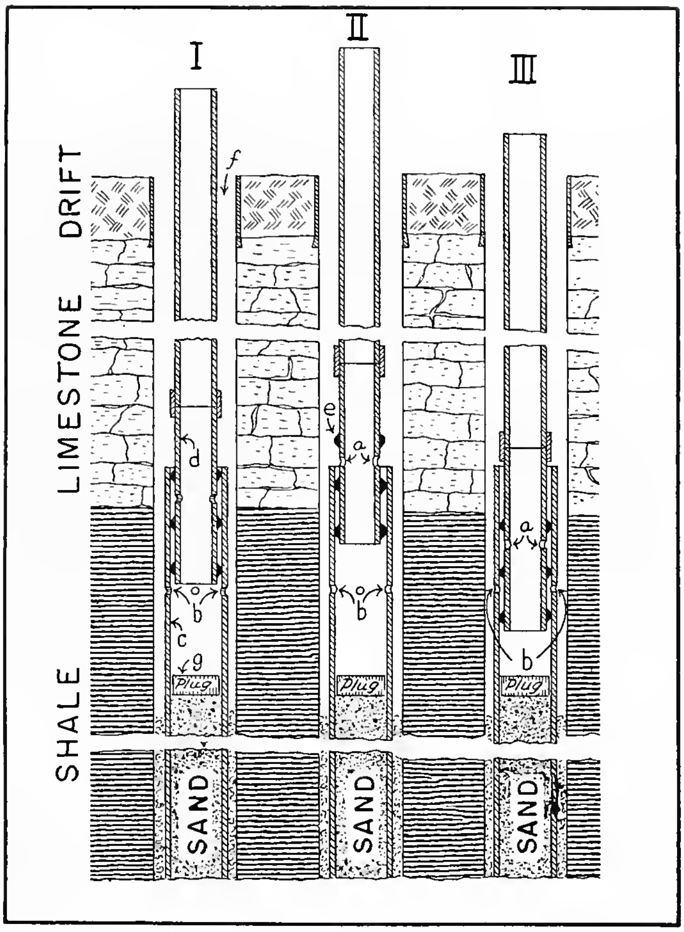
be set above the grout perforations, water testing and flushing carried out and then, as the grouting proceeded, samples could be taken of the water just above the packer to determine when cement started to enter the casing at higher perforations. The grouting should be stopped when cement enters the casing above the packers and sufficient mud or water pumped in to fill the grout tube and also the casing between the packer and the grout perforations. If a considerable quantity of cement enters the casing above the plug it would be wise to keep the water above the packer agitated with air or with a plunger in order to prevent the cement from settling against the top of the packer and hardening there. After allowing five or six hours for the grout to take an initial set the packer could be released and removed. The well could then be filled with sand to a point below the next higher perforation, the packer reset, the opening flushed and grouting continued on up the well, repeating the process as many times as necessary.

A double packer plug of the type used in oil well squeeze cementing or of the air expanded type could be used for grouting through perforations and thus avoid the need for filling the well with sand above the aquifer plug at the bottom.

A Bacon Bomb type sampler 26/ , Figure 27 is suitable for sampling above the packer to determine when cement is entering the casing at perforations above the injection point. These samplers are designed to obtain samples at the very bottom of tanks or from any intermediate level. They can be purchased in eight ounce, 10 x 2" and 4 ounce 11 1/2 x 1 3/4" size for about $17.00. So far as is known they have never been used in well investigations but could be made to serve a variety of purposes. Smaller diameter samplers could be made up along the same lines if necessary.

If the results of test pumping into perforations or other information indicates that large cavities have been eroded in the material outside the casing it may be worth while to explore for cavities with small test holes before undertaking repair operations. This was done at Western Electric Well Number 2 in which the chlorides had increased to several hundred parts per million and the water was no longer usable. This well was drilled in 1930 to 313 feet depth and is located close to the Patapsco River on Point Breeze. A two inch hole was sunk outside the casing and struck a large cavity at 90 feet below the surface. The test hole was enlarged to four inches and 150 tons of pea size gravel fed in. A grout pipe was then worked down into the gravel and grout pumped until it appeared at the surface.

26/ A. S. T. M. Designation D 270.



I II III

Fig. 26 Bottom Hole Casing Connection for Grouting an Old Well. Drawing from "Grouting Procedures", Louis T. Watry, The Driller, Vol. 11, No. 7. July 1937.

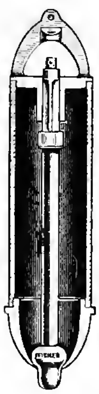


Fig. 27 Bacon Bomb Type Sampler. Drawing from Fisher Catalogue 90.

The chlorides soon dropped to about 35 parts per million and the job was considered successful.

The above job was planned and supervised by Mr. E. S. Adams, Plant Engineer. Since the well drillers he contacted would not undertake the job Mr. Adams called in the Raymond Concrete Pile Company to drill the test hole and do the grouting.

The methods described above for repairing leaky wells are sure to be expensive. However, if they prove successful in the majority of applications the expense will be well justified. Other schemes might be devised which would be less costly but if these are not based on an accurate knowledge of the underground conditions and on good grouting practices, they are very apt to fail with the result that the well and all the money invested in repair is lost. Moreover, the job of completely sealing up the well must then be undertaken or the well will remain a permanent source of contamination.

Sealing Abandoned Wells

With an understanding of the methods and techniques available for grouting new and repairing leaky wells the planning of procedures for permanently sealing abandoned wells becomes relatively simple. The rules which should be followed to accomplish the job with fair certainty of success are:

1. Clean out the well and remove as much as possible of the old casing.

2. Thoroughly perforate all casing left in the well to permit free circulation of grout into the cavities outside. The more and the larger the openings in the casing the better.

3. If the aquifer at the foot of the well is apt to take grout plug it with sand.

4. Pump the grout to the bottom of the well in one continuous operation.

5. If the well cannot be filled with grout all the way to the surface because of the presence of an open formation, stop when the grout has risen to this formation. Allow the grout in lower part of the hole to set, then plug the open formation with sand and continue the grouting to the surface.

The many unsuccessful attempts to completely plug abandoned wells in this area is believed to be due to the fact that cement or clay is not worked into the cavities around the casing. Any steps taken to assure filling of these outside cavities will increase

the chances of success. Thus the more old casing removed and the more holes punched in any casing left in the well, the better. In double or triple cased wells the inner strings should always be removed, if necessary cutting each string at the foot of the casing next outside. If it is impossible to remove the inner strings then the perforations must penetrate both inner and outer casings. For this a gun perforator might be used. See Figure 28.

Where casings are left in the well and are perforated it would be a good idea to agitate the grout with a plunger as it rises in the casing to assure continued flow into the outside cavities until they are filled. The desired condition is for the grout to rise outside the casing at the same rate it rises inside.

Many of the old wells in the area have been filled with concrete without removing the casing or making any attempt to seal the cavities and channels in the ground outside. As a result some of these old so-called "plugged" wells are leaking seriously. The job of rectifying these past mistakes is sure to be a costly and difficult one. The job of drilling out the concrete and attempting to remove what is left of the old casings would appear to be a more expensive job than drilling a new hole alongside the old well and working down it, in efforts to seal the cavities and vertical channels. The latter attack has the advantage of providing exploratory evidence as to the underground condition as well as being cheaper and providing an uncased hole to work in.

Most of the old wells throughout the area have simply been abandoned when the screens or casings failed or salt and acid contaminated the producing aquifer. Many of these are no doubt still transmitting salt and acid to the lower beds. Whether natural processes ultimately seal these leaks and what length of time may be required for natural plugging can only be guessed. It is reasonable to suppose that in many cases when pumping is stopped the products of underground erosion and casing decomposition, carried down by the leaking water, will gradually clog the lower aquifer around the well and ultimately seal the leak. That this does not always take place is evidenced by the continued leakage down the plugged wells in certain areas where nearby wells are still heavily pumped. Probably the heavy pumping prevents the gradual deposition of suspended particles in the aquifer around the old well and keeps the leak open.

If the actively leaking abandoned wells can be located there is some possibility that government assistance might be obtained to do the sealing job. Governmental sealing of abandoned coal mines to protect surface waters affords a precedent that applies to the sealing of abandoned wells to protect underground water. The United States Department of Interior Geological Survey is always willing to lend the assistance of the ground water experts on its staff and to do everything within its means to help correct the type of difficulties that have beset ground water users in the Baltimore Industrial Area.

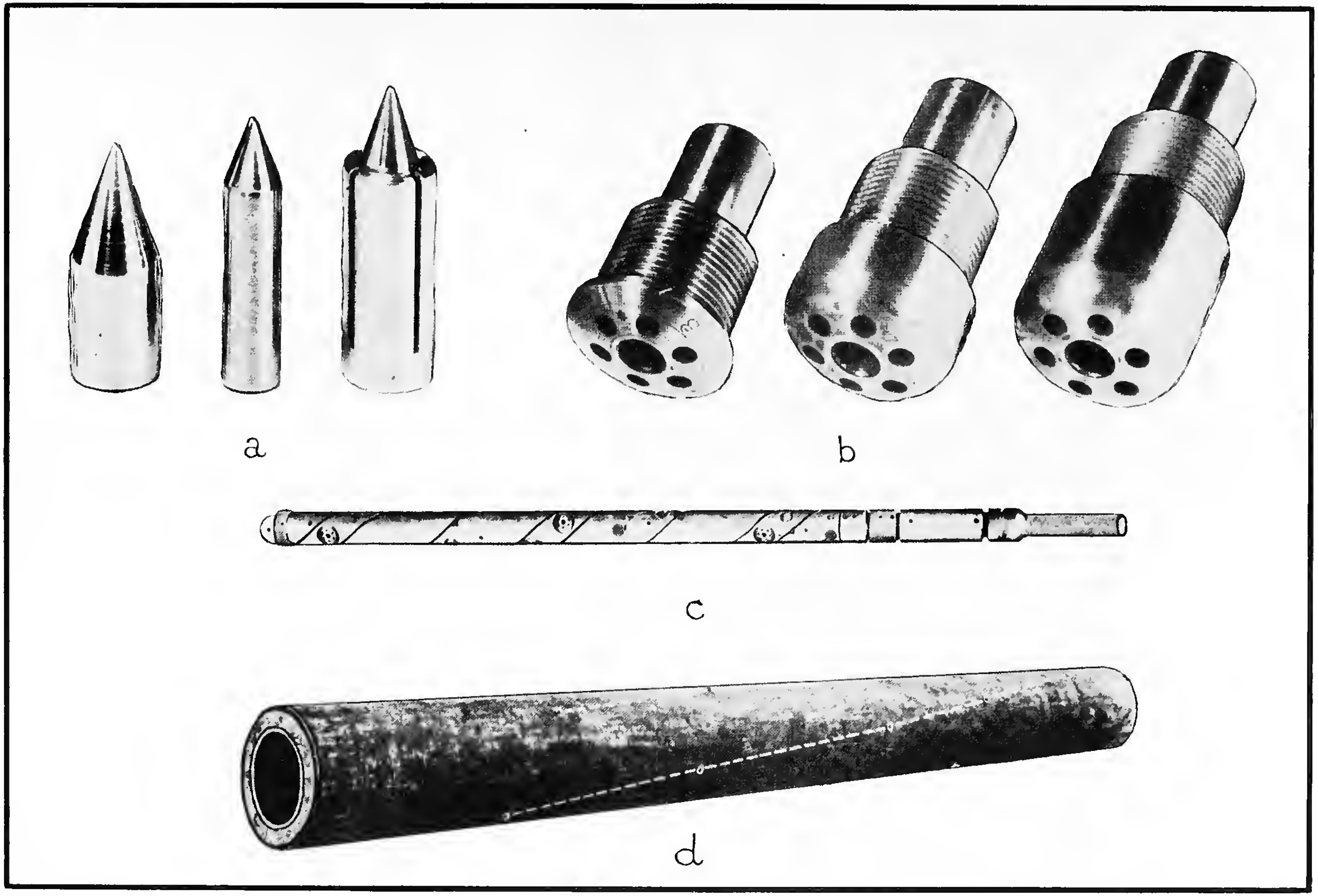


Fig. 28 Schlumberger Gun Perforator. (a) The bullets, (b) the cannon, (c) the gun, (d) perforations through two casings, one cemented within the other. Illustrations from a booklet published by the Schlumberger Well Sampling Corporation, Houston, Texas.

SECTION VI

SUMMARY

The difficulties connected with the utilization of ground water in the Baltimore Industrial Area, and the methods which may be used for studying and correcting these difficulties have been summarized in the introduction, Section I, of this report. It appears desirable, therefore, to present in these closing paragraphs only a brief enumeration of the salient problems and the means which should be adopted to solve them.

Ground water used in the Baltimore Industrial Area is withdrawn from the sands and gravels of the unconsolidated Cretaceous formations of the coastal plain along both sides of the Patapsco River southeast of Baltimore. This artesian water enters the pervious beds through outcrops that appear in irregular bands along the Fall Line and moves thence southeast between thick confining beds of clay.

Since the time this water was first used by the early settlers more than 1000 wells have been drilled in the area. It is estimated that about 40 million gallons daily are pumped from 150 large active wells. The value of this water to the Baltimore area is about $1,000,000 annually.

Five types of difficulties are encountered in connection with the utilization of this ground water. (1) Contamination with salt. (2) Contamination with acid waters. (3) Fall in static levels. (4) Reduction in yields. (5) Structural failure of the wells or well equipment.

Of these, chloride contamination is the most serious. In the area around the upper Patapsco River salt water has entered the aquifers through their outcrops under the harbor or through the many abandoned wells and has thoroughly contaminated all the artesian strata. The high chlorides in some wells indicate that the water is pulled through underground channels directly from the river. This area of general contamination does not appear to be spreading appreciably. Movement of salty water down the dip would be very serious and might spell the doom of fresh ground water supplies along the lower Patapsco River.

In the Colgate Creek, Dundalk, Sparrows Point, Fairfield and Curtis Bay areas the deep aquifers are still fresh. In these areas many wells are contaminated by leakage of shallow salty water down used and abandoned wells. Prospects are favorable for correcting these difficulties if the proper records are kept and scientific methods of testing, diagnosis, and treatment are adopted.

The types of records needed are: (1) Continuous recording of static levels at strategic points. (2) Accurate meterage of

all water pumped. (3) Frequent tests of static and dynamic levels in active wells. And (4) frequent check on chloride content of water from active wells.

The detailed studies needed are: (1) A general study of logs and of water quality and static levels in order to correlate the various distinct aquifers. (2) Study of water levels, rates of use, and hydrology to determine the safe yield of the aquifers in the area. (3) Location of the limits of the area of general contamination and study of its rate of extension. And (4) intensive study of the leakage problems at the individual well groups to learn the source, the manner and the amount of leakage in order that successful corrective measures may be planned.

The hydraulic and geochemical methods available for making these studies are elaborated in the body of the paper.

A great deal of time has been spent during the present investigation in tabulating and summarizing information from all the existing sources in order that it may be used more readily in studies of the above type now under way as a cooperative project sponsored by the Maryland Department of Geology, Mines and Water Resources, and the U. S. Department of the Interior Geological Survey. Adequate scientific data accumulated in connection with the latter project should in the course of a few years provide the answers to many of the perplexing problems and indicate the correct solutions for the individual difficulties.

The serious leakage of salt and acid contaminated waters from shallow water bearing formations into the deeper fresh water aquifers can be controlled only by proper use of cement grout for the construction, repair and sealing of wells. Many of the techniques for using cement grout have, therefore, been described in detail. Unless these methods are adopted most of the ground water supplies in the Baltimore Industrial area will sooner or later have to be abandoned as sources of fresh water.

A P P E N D I C E S

APPENDIX I

List of Wells in the Baltimore Area

In order that the soope, the limitations and the possible uses of the list of wells may be clear, the sources of information are described here, and reasons are given for working up and presenting the information in the particular form used.

Sources of Information

The fact that so much data on wells in the area could be assembled is due to the interest and the work of numerous public and industrial officials. Darton 3/ made the first fairly comprehensive survey of wells, in the area. His work served as a stimulation and guide for the later surveys made by the Maryland Geologic Survey. The early work of the Survey seems to have been very thorough, and records apparently were kept fairly well up-to-date until in the early 1930's. In 1939 the severe ground water difficulties at the Sparrows Point plant of the Bethlehem Steel Company interested the officials of the Plant in the general problems of the area, and they stimulated much of the work which led to the preparation of this dissertation.

In order that the various sources of information might be known to future workers, reference index letters are recorded in Column 26 of the comprehensive list. The key for source reference letters is shown in Table XVI.

TABLE XVI

Key to Reference Letters Used in the
List of Wells in the Baltimore Area.

A. Bethlehem Steel Company Files and Surveys.
B. "Report on the Curtis Bay Water Supply for the United States Industrial Alcohol Co." Dr. J. T. Singewald Jr., December 8, 1920

3/ N. H. Darton, "Artesian Well Prospects in the Atlantic Coastal Plain Region". U. S. Geological Survey Bulletin No. 138, 1896.

* Sources D, E, F and G are at present available to any interested party. All letters, reports and data sheets comprising sources A, B and C are included in the supporting data with numerous other papers pertaining to the ground water situation in the area.

C. The Shannahan Artesian Well Company letters to the Bethlehem Steel Company.
D. The Maryland Geological Survey Index and Record Cards.
E. The Files of the Bureau of Water Supply. Baltimore City, Cross-Connection Surveys.
F. "Artesian Well Prospects in the Atlantic Coastal Plains Region". N. H. Darton, Bulletin 138, United States Geological Survey, 1896.
G. "Water Resources of Maryland". William B. Clark, E. B. Mathews, and E. W. Berry. Maryland Geological Survey. March 1918.
H. Information directly from Owners not included in above surveys and reports. Obtained by Geyer.
I. Information obtained during the present cooperative Maryland Geological Survey Study.

Maryland Geological Survey Records

The records kept by the Maryland Geological Survey are the most important source of information on wells in Maryland. Where actual field surveys have been made and the existence of wells learne by door to door canvass, the records are complete. When voluntary reporting and occasional correspondence with well drillers has been depended on for information tho coverage is apt to be rather poor. In the Baltimore area several intensive surveys have been carried out by the Geological Survey. The first and most thorough of these was made around 1910 and shortly thereafter and formed the basis of the information published in the 1918 report "Water Resources of Maryland". The last survey was undertaken as a CWA project in the early 1930's when data were collected for preparation of a contour map showing elevations of the basement rock in Baltimore City. The principal shortcoming of the latter survey seems to have been that no effort was made to obtain full information from the large industri For example, very few wells of the two largest ground water users, the Bethlehem Steel Company and the U. S. Industrial Chemical Company, appear in the Maryland Geological Survey records.

The following records are available in the files of the Maryland Geological Survey:

I. - The State-Wide System

a. Card Index giving data on each well reported outside the Baltimore Area. On these 3 x 5 inch cards are recorded data obtained firsthand or submitted by the owner or driller. They are

filed in groups according to the United States Geological Survey Topographic Quadrangle in which the wells are located and are given a serial number and a location number. The location number is based on the usual successive 3 x 3 subdivisions. The subdivisions are numbered 3 times across from 1 to 9 as reading. The first numeral in the location number indicates the rectangle in the first 3 x 3 breakdown, or in this case the 5 minute x 5 minute rectangle in which the well is located. The second numeral signifies the location in the further subdivision of the first rectangle, etc. The names are abbreviated and followed by the location numbers, e.g., Bal-9-639 indicates the Baltimore Quadrangle, the last or lower right hand 5 x 5 minute rectangle, and the further location by 3 successive 3 x 3 breakdowns. The cards for each quadrangle are filed by location number. File drawers are numbered "Well Records" 1, 2 and 3.

b. <u>Book of Quadrangle Sheets</u> showing the wells as red circles, with well serial number. The book contains a transparent location number grill and a key to symbols used on the cards.

c. <u>Book of Profiles</u> showing wells and well logs projected onto seven sections running from Fall Line to the Atlantic Ocean. Vertical Scale 1" = 100' and Horizontal Scale $\frac{1}{62500}$.

II. <u>Baltimore Area Record System</u>

a. <u>Card Index</u> giving data on each well similar to the plan used for the State. The location system is referred to Maryland Geological Survey maps, scale 1" = 1000'; of which there are seven, each covering an area 4 miles E-W, by 5 miles N-S. The four Baltimore maps corner at the Washington Monument and are called 1N1W, 1N1E, 1S1W and 1S1E. Three additional maps cover the industrial areas down to the Patapsco River. These three maps are referred to on the cards by either of two names 1S2E or Dundalk, 2S1E or Curtis Bay, 2S2E or Sparrows Point. Each map is subdivided into 1/2 mile squares. The 8 columns formed are numbered 1 to 8 across the 10 horizontal rows 0 to 9 downward. Each half mile square block is indicated by

its row number followed by its column number. These blocksare then further subdivided by successive 3 x 3 breakdowns as in the case of the quadrangle maps, thus giving location numbers which read as 1S1E-46-475. This system is a revision of an earlier one based on letters and numbers using half mile squares but not relating them to the 4 by 5 mile sections of the map. The latter numbers appear on most cards as well as the regular location numbers. Wells on each of the 4 by 5 mile blocks have been numbered by one or the other of several serial numberings. As a consequence the serial numbers have lost significance except in connection with the use of the spotting maps, where by using the location number, the serial on the maps can be checked against the serial on the card. The area covered by the seven maps of this system is also covered by the U.S.G.S. Quadrangle sheets. Some of the wells in the Baltimore area are filed under the statewide system rather than under the Baltimore Area system. Because of this overlapping and because of the changes in the old numbering systems a good deal of difficulty is encountered in working with these records. Filed with the well cards are hundreds of cards giving information on test borings in the Baltimore area. Thus there are many hundreds of mixed well and test boring cards classed according to the reference maps and arranged in sequence by location number. They are filed in a shoe box that is kept on any handy shelf.

b. <u>Book of Maps</u> which goes with the above index system contains for each 4 by 5 mile area the following:

<u>For 1N2W</u> (A small strip in the Western edge of city)

1. Vellum original showing spotted wells, well serial numbers, basement rock elevations and basement rock contours.

<u>For 1N1W</u>

1. Vellum original showing 8 cross-sections plotted to scales 1" = 1000' horizontally and 1" = 300' vertically.
2. Vellum original showing rock contours.
3. Vellum original showing spotted wells, well serial numbers, bed rock elevations and rock contours.

4. Maryland Geological Survey Topographic and property map published June 1912, called 1N1W, on which are shown some wells marked with serial numbers different than on rock contour sheet, and on which is superimposed the surface geology.

For 1N2E (A small strip in the eastern edge of the city)

1. Vellum original same as for 1N1W.

For 1N1E

1. Vellum original showing structure contours of pre-cretaceous unconformity.
2. Vellum original showing profiles.
3. Vellum original of rock contours.
4. Vellum original showing spotted wells and borings, rock elevations and contours.
5. Maryland Geological Survey Topographic and Property map published July 1913 on which is shown surface geology.

For 1S2W, 1S1W, 1S1E, 1S2E or Dundalk, 2S1E or Curtis Bay and 2S2E or Sparrows Point. The information presented runs much the same. Along the river the original shore lines are shown.

The above type of information would normally not have to be discussed, but in this case the systems are mixed and not well-understood and most of the maps and drawings are without title. Therefore the systems are described so that subsequent investigators may know what is available and the form in which it will be found. The preparation of these records represented a tremendous amount of work. They should be straightened out, be completed and be kept up-to-date. A start in this direction has been made in the present work.

The New Well Numbering System

In the above discussion it may have been apparent that the old system of recording well locations in the Baltimore area had certain shortcomings. Among these are: (1), the numbers were related to a particular set of old maps which did not cover the entire area; (2), the numbers gave no readily apparent idea of the general location of the well; (3) the numbers were long and cumbersome; (4), there was no convenient way to extend the system beyond the limits of the particular

reference maps; and (5), the location designation system is not the one accepted and used in the area for all other purposes.

Therefore, the following system was adopted. Using the Washington Monument as the point of departure, each mile square was designated by its distance either N or S and E or W. Thus, 2S3E indicates the mile square enclosed by the second mile south and the third mile east of the Monument. These squares may then be broken down by successive 3 x 3 subdivisions as desired to indicate exact location. The advantages of this scheme are apparent. This is the system that is used by all other public agencies in the area. The City of Baltimore has prepared very detailed maps to a scale of 1" = 200' for each mile square in the city. These are being used in the present cooperative study to accurately spot each well considered in the investigation.

Explanation of the List of Wells.

In order that the significance and the limitations of the information presented in the List of Wells in the Baltimore area be fully understood, each column in the List is explained below.

1) Table Line Number. For reference use only.
2) Old Maryland Geological Location Number. Every well recorded in the Baltimore Area file which is related to the seven Maryland Geological Survey 1" = 1000' scale maps has been listed. All the wells recorded in the Maryland State Quadrangle file which fall both in the area of the seven Baltimore maps and in the coastal plain have been listed. In addition a number of wells outside the Baltimore area maps, have been included either because of some particular significance or because considerable data on them were obtained in connection with the recent field surveys. The list of wells does not include more than a small portion of the wells in the area outside that of the seven Baltimore maps.
3) New Mile Square Location Numbers. The mile square locations are listed for all wells except a few filed according to the statewide system.
4) Owner's Number. The numbers given are the most recent numberings used by the various owners. There is sometimes difficulty in working with owner's numbers for the systems are changed

from time to time as old wells are abandoned and new ones drilled. The U. S. Industrial Chemical Company numbers its wells according to the property number on the pump motor and pump frame. Occasionally the motors are switched and confusion results.

5) Owner. After exhausting all existing sources of information as to possible well owners, the Baltimore Directory was searched to determine present company officials and addresses. Each company that was still in existence was circularized to determine the present status of its wells. Cards were also sent to a number of companies that might possibly have been well owners but on which no information had been obtained. The fact that none of these spot-checked companies had wells indicates that the list is fairly complete. The cards used are shown in Figure 29. They were printed and mailed by the Maryland Department of Geology, Mines and Water Resources.

Mahy of the properties on which wells were drilled in early days have changed hands several times. As a result numerous duplications of wells listed under the name of successive owners were discovered. When found these were cross-referenced to indicate clearly that the same wells appeared in the record as property of different owners. There are no doubt other cases that will be discovered when the location of the wells is accurately determined in the field.

6) Address. The addresses listed in the table are those given in the sources of information. Since the time when the early surveys were made by Darton and by the Maryland Geological Survey numerous street names have been changed. Research into the history of changes in Baltimore street names did not appear justified so only those changes that could be determined by comparing old maps with new ones were figured out. In Table XVII are shown the most important name changes. In the cross-reference table which follows the main list the changes in names have been made so the street addresses for the owners in each mile square correspond to those on the latest maps.

State of Maryland
Board of Natural Resources
Department of Geology, Mines and Water Resources
Baltimore, Maryland

Due to widespread and continuing deterioration in the quality of ground water in the Baltimore Industrial Area, there are increasing demands for a complete investigation of the ground water situation and for assistance in establishing conservation measures. In order to meet these demands this department requests the cooperation of all industries owning property on which wells have been drilled.

The attached card asks for preliminary information needed to plan a comprehensive conservation program. Your assistance will help conserve the water supplies of many industries and will thus reduce the magnitude of Baltimore City's water supply problems. Thank you for your cooperatio

Edward B. Mathews, Director

Conservation of Ground Water in the Baltimore Industrial Area

RECORD OF WELL OWNER

Have wells ever been drilled on your property? Yes ☐ No ☐

Is well water now used for any purpose? Yes ☐ No ☐

Total number of wells drilled on property of owner: ----------------

Number of wells abandoned: . . . . ----------------

Number of wells in use or equipped for use: . . . . . ----------------

Approximate quantity of well water used: ------------------------------

Would you like to receive a recent paper describing the "Ground Water Situation in the Baltimore Industrial Area"? Yes ☐ No ☐

Is your company interested in active cooperation in this work?

Yes ☐ No ☐

Signed:------------------------------------

Title:--

Figure 29. Cards Sent to all Known or Probable Well Owners.

TABLE XVII

CHANGES IN AVENUE AND STREET NAMES IN HIGHLANDTOWN AND CANTON

Changes in Name of Avenues		E - W
1st Avenue	=	Boston Street
2nd Avenue	=	Cardiff Avenue
3rd Avenue	=	Danville Avenue
4th Avenue	=	Eastbourne Avenue
5th Avenue	=	Holabird Avenue
6th Avenue	=	(No streets
7th Avenue	=	(today
8th Avenue	=	Jencks Avenue
9th Avenue	=	Keith Avenue
10th Avenue	=	Leland Avenue
11th Avenue	=	Mertens Avenue
12th Avenue	=	Newgate Avenue

Changes in Name of Streets		N - S
1st Street	=	Highland Avenue
2nd Street	=	Baylis Street
3rd Street	=	Conkling Street
4th Street	=	Dean Street
5th Street	=	Eaton Street
6th Street	=	Fagley Street
7th Street	=	Grundy Street
8th Street	=	Haven Street
9th Street	=	Iris Avenue
10th Street	=	Janney Street
11th Street	=	Kresson For
12th Street	=	Lehigh &) 2 blocks N
13th Street	=	Macon) 2 blocks S) of Eastern Avenue.
14th Street	=	Newkirk Street
15th Street	=	Oldham Street
16th Street	=	Ponca Street

Canton Street is probably now Fleet Street

7) Diameter in Inches. Generally the diameter given is that of the smallest string of casing or liner pipe used in the well.
8) Approximate Surface Elevations. The figures for elevation of the ground surface of the well were taken from the source material when given or were estimated from existing topographic maps if needed in connection with the present studies. They cannot be considered accurate within plus or minus five feet and in a few cases the discrepancies may be much greater.
9) Depth to Bottom of Well. The depth is the measured distance from the surface or a point of reference not far above the surface to the bottom of the drilled well. Owners and well drillers commonly call the depth the distance to the bottom of the well screen. These minor discrepancies in depths often appear in the different sources of information.
10) Depth to Bottom of Casing. This is taken as the depth to the top of the uppermost screen set in the well.
11) Depth to Main Supply. Where possible depths to both top and botton of each aquifer have been given. A few depths to supply may be to the top of the aquifers rather than to the bottom because drillers frequently report depths to the point where water is first encountered.
12) Depth to Subordinate Supply. Same as for depth to main supply.
13) Depth to Bottom of Potomac Formation. This is the depth to the crystalline basement rock.
14) Date Drilled. So far as is known these are the dates the wells were drilled but old wells are sometimes deepened or rebuilt so some of the dates given may actually apply to the time changes were made.
15) Original Static Head in Feet from Surface. Data are supposed to be the original static head at time of drilling unless otherwise indicated. However, much of the information taken from Darton's report and the report of the Maryland Geological Survey may actually apply to the time these early surveys were made.
16) Static Head 1940-1942. Static heads measured by various workers during recent investigations. They are the latest data collected. The magnitudes indicate the general artesian pressure conditions throughout the area when most of the other active wells are in operation. The static

levels are all downward from the surface unless specifically labeled plus.

17) Original Yield in Gallons per Minute. Only approximate data are available and a good many values represent deliveries under special test conditions rather than operating rates. Some of the yields figures are no doubt little better than rough guesses. Yield data are supposed to be original unless otherwise stated but may actually apply to the time early surveys were made.

18) 1940-1942 Yield in Gallons per Minute. Latest data available. Accuracy same as for original yields.

19) In Use 1942. Only those checked that are actually known to be in use.

20) Abandoned by 1942. Only those that are known to be abandoned are checked. Presumably practically all the wells not known to be in use have been abandoned. There are some wells, however, whose use has been discontinued but which could easily be hooked up or repaired and used again. It is difficult to know whether or not to designate these as abandoned. The policy followed was to check wells as abandoned only when there was almost no possibility of their ever being put in condition for further use.

21) Log Available. Logs for all wells checked in the log available column have been included in this report in a separate table of logs. They are arranged alphabetically by owners and cross-referenced to the sheet and line number of the main list. The list of logs is complete as far as reports and public records are concerned, and is believed to be a fairly complete listing of logs available in well owners' files. The only unused sources that may contain considerable additional information on well logs are the files of well drilling companies that have operated in the area.

22) Record Sheet Prepared This column is checked when a special survey record sheet has been prepared for the well. Since these record sheets have already been copied and are now being used in connection with the cooperative study and as the most important information appears in the tabular list, they are not reproduced here. They may be found with the supporting data.

23) Geologic Horizon. The following key is used:

Q	Pleistocene	
Kpa	Patapsco	(Lower
Ka	Arundel	(
Kpx	Patuxent	(Cretaceous
K	Potomac Group includes the above three	(
	Crystalline Rocks.	

The geologic horizon has been stated only when the information has appeared in earlier reports. The horizons indicated are not necessarily to be considered correct. No attempt was made to indicate geologic horizons when they were not stated elsewhere because it is not felt that the stratigraphy is sufficiently well worked out to justify naming the age of the various aquifers which appear at different depths throughout the area.

24) Character of Water. This is stated when information is available. Many analyses of well water quality have been made by the very large industrial users. A large amount of this information was collected and appears in the supporting data. It is not reproduced here because of its volume and because the data collected represented only a part of total that is available in the files of the various industries. Typical analyses are presented and discussed on page 67.

25) The Driller. The well driller is stated only when definitely known. It may, however, be assumed that since about 1900 the Shannahan Artesian Well Company has drilled practically all of the wells for the large companies who have some wells listed as known to have been drilled by Shannahan.

26) Sources of Information. These are discussed fully on pages 16 and 17. The reference letters refer to the key given in Table XVI, page 111 and 112.

27) Remarks. These include special information, cross-referencing notes, etc. If the line of information covers more than one well this is so stated in the remarks. Some lines in the list apply to old groups which contained as many as twenty wells.

On the Maryland Geological Survey cards there frequently appear numbers after the symbols W, H, and B. These have the following significance:

W = Elevation above tide of the top of the well
H = Static head above tide

B = Bottom of well above tide.

These numbers are reproduced in the remarks column of the List of Wells in the Baltimore Area.

LIST OF WELLS IN THE BALTIMORE AREA

SHEET No. 1

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in	Approx Surf Elev Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sked	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Rel 1-117			All Saints Convent	Sollers Point			30 & 120								12							Good. Hdn = 45		D	(2 wells. Address also (given as Orange Grove (Catonsville
2		5S6E-		Aluminum Ore Co.	Turners Station	8	12	160		160						100						Kpx	Boiler use	Shannahan	G	
3		1S1E-		American Building	Balto. & South Sts.																				E	
4	1S1E-46-475	3S3E-		Am. Agr. Chem. Co.	Foot & Clinton St.	8	5	230		230			1897	20 to 30		Large			x			Kpx		Rust	G,E,D	
5	1S1E-46-475	3S3E-		" " " "	" " "	6	5	240		240			1902			Good			x			Kpx		Rust	G	
6		1N2E-		Am. Brewery, Inc.	Gay & Lanvale Sts.																					See Weissner's Brewery
7	1S1E-46-475	3S3E-		Am. Chemical Co.	Clinton & Leland	4		180+					1896±			132									D	(Only well. In (Orenatox) (in 1934
8	1S1W-5-468	1S2W-		American Ice Co.	Franklin & Pulaski Sts.	6	132	242		200			1911	14		60						Crys.	Very good	Downin	G,D	Water at 200, Rock at 151'
9	1S1W-5-468	1S2W-		American Ice Co.	Franklin & Pulaski	6	132	200		200	33'		1911	15		40						Crys.		Downin	G,D	Water at 200, Rock at 20'
10	1S1W-17-148	1S1W-		American Ice Co.	Schroeder & Balto.	6	75	1017								20				x		Crys.		Downin	G,D	Hard granite at 60
11	1S1E-21-379	2S1E-		American Ice Co.	Hughes & Henry	6	5	110-136		110-136			1899	5		All 6/5						Kpx			G,D	8 wells
12	1S1E-23-616	2S2E-		American Ice Co.	Wolfe & Fells	6+ 8	5	145-165		145-165				20		Large						Kpx			G,D	12 wells connected
13		2S2E-		American Ice Co.	Wolfe & Fells		5	157		155-157		137		15		300						Kpx			G	(Reported by Darton but (not verified. 2 wells (157
14		2S2E-		American Ice Co.	Wolfe & Fells		5	317				137										Kpx			G	
15	1S1W-17-148	1S1W-		American Ice Co.	Schroeder & Balto.	8	74						1904											E. Art. Well Co.	D	Rock at 45'

SHEET No. 2

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		2S4E-	1	American Radiator & Standard Sanitary Corp.	Holabird & Quail	12	27.5	279		174		279	1926	50	80	216	100	x		x	x		Very good 1942	Guar. W. Eng'g. Co.	A	(Owners say depth is 174' (caved in in 1942 (since repaired
2	1S1E-33-174	2S2E-		Am. Sugar Refining Co.	Key Hwy.& Ft. Woodall			195												x	x				G,D	
3		3N1W-		Appold, L. T.	3503 N. Charles St.	6"	240	125		125				21		9						Crys.			G	
4	1S1W-18-581	1S1W-		Armour & Co.	Pratt & Eutaw Sts.	6	40	178		178						40-50						Crys.		Downin	G,D	Rock at 45'
5	C.B.-34-233	7S2E-		Armour Fertilizer Co.	Curtis Bay		11	342					1918	21.96	41			x					Cl = 4 ppm 1942		A,B,D	
6	Rel 3			" " "	" "	6		420					1918	30											D	
7				Artesian Water Co.	Howard Park																				W.B.Clark Report	5 wells
8		4S1E-	1	Arundel Corp.	Brooklyn		10	234										x			x		Water good 1942 Chlorides 29.1 ppm		A,B	(Probably (same (well
9	1S1E-72-466	4S1E-		Arundel Sand & Gravel Co.	Brooklyn			238																	B,D	
10	Rel 2-4			" " "	Glen Burnie	38		65					1927			178						42'clay fine S		Layne Atl.	D	Drawdown 55'
11	1S1E-75-661	4S3E-		Arundel Ship Building	Fairfield			31																	B,D	
12				Atlantic Terminal Inc. = B =	Childs Rd.,Brooklyn		8	265					1913					x			x		Cl = 48 ppm 1941		A,D	
13	Bal 9-639			Back River	Nr. Frosset Park			209					1896			Dry								O'Donovan	D	W = 45; B = -164
14	Bal 9-639			" "	" " "			60					1896			20						Sand, gravel & clay		"	D	Not used
15	1S1W-15-717	1S2W-		Balto. Brewing Co.	Pratt & Frederick Ave.		100	310								18						Crys.		Downin	G,D	Plant closed 1910
16	1S1W-4-573	1S3W-		Balto. Butchers Abbt.	2601 W. Franklin St.	6		503					1929			14								C. Hoshall	H,D	Rock at 15'
17		5S3E-		Balto. Chrome Works	Eswall, Fairfield	4		155						2		10-15									F	
18		5S3E-		" " "	" "			562								none									F	

SHEET No. 3

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E 22-916	1 or 2S1E-		Balto.City Public Wells	Central & Eastern Ave.			50								Large			x						F,D	Condemned by Health Dept.
2		2S2E-		" " " "	Wolfe Nr. Lancaster											Many			x						F	
3		2S2E-		" " " "	Arm Nr. "											Many			x						F	
4	Gun 7-441	1S7E-		" " " "	Back Rr. Sew. Disp. Plant	6	25-30	156	146	146-156	10,18 20		1909	15		15						Kpx		Hoshall	D,G	(W = 45,H = 30,B = -111 (A = 111,A' 35, A'' 27 (A''' -85
5		1 or 2S1E-		" " " "	Aliceanna & W. Falls Ave.	3	10	112		70									x			Q	Poor, condemned		G	
6	Bal 9-3493			Balto.Co. School Bd.	Rosedale, Md.	6		234					1920			15						Kpx		Hoshall	D	W = 65; B = -169
				Balto. Co. School Bd.	Fort Howard School																				C	See under Fort Howard
7				" " " "	Lodge Forrest School			307					1930											Shannahan	C	
8	1S1E-36-165	2S3E-		Balto. Copper Wks. Co.	1st & 3rd Ave.			165								12			x		x				F,D	(Now Am. Smelting & Ref.Co. (Depth was 2/2 to rock. (Filled to 165
9	1S1E-36-165	2S3E-		" " " "	" " "	8		114								75			x						F,D	
10	1S1E-36-165	2S3E-		" " " "	" " "			50								10 ea.			x						F,D	6 wells
		2S3E-		" " " "	" " "			214					1906	36										Shannahan	C	
11	1S1E-36-534	2S3E-		Balto. Cu.Smelt. & Ref. Co.	4th Ave. & 5th St.	8		225-240					1903 1905	50		750 in all			x		x			Shannahan	D	4 wells
12	1S1E-36-578	2S3E-		" " "	" " "	6		225					1903	50		45			x					Shannahan	D	Water in fine gravel.

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1W-37-346	2S1W-		Balto. Distilling Co.	Russell & Carey Street	2½	10	40		37-40			?1904 1914	10		250 all						Q	Poor	Balto. Art. Well Co.	G,D	4 wells. All in gravel
2	1S1E-44-	3S2E-		Balto. Dry Dock	Adj. Ft. McHenry	6	5	118		118			1904	20		Large						Kpx			G	
3		2S1E-		Balto. Dry Dock	Ft. of West Street	2½	5	72		72						Many						Q			G	
4	1S1E-44-293	3S2E-		Balto. Dry Dock	Port McHenry	6	5	167								100					x	Kpx			G,D	Now Bethlehem Ship bldg. Repair Yard. Rock at 162'
5		3S2W-		Balto. Enamel & Novelty Co.	Ontario St. & B & O RR																				E	
7	1S1E-46-417	3S3E-		Balto. Guano Co.	Clinton & 9th Ave.	12	10	125								Many						Kpx			G,F,D	Darton Report not verified in 1910
8	1S1E-46-417	3S3E-		Balto. Guano Co.		3	10	170								Many						Kpx			G,F,D	
9	1S1E-46-417	3S3E-		Balto. Guano Co.	Clinton & 9th Ave.	3	10	220								Many						Kpx			G,F,D	
10	1S1E-46-417	3S3E-		Balto. Guano Co.	Clinton & 9th Ave.	3	10	80								Many						Kpx			G,F,D	
11	Bal 3-41			B & O RR	Baltimore	10	12	240					1921			225-250			x				Hard	Layne-Bowles	G	
12	CB 4-639	6S2E-		B & O RR	Coal Pier, Curtis Bay	10	12	315					1920						x	x	x				B,D	3 wells in group log for deepest
13	C.B.Q.5-471	6S3E-		B & O RR	Old Pier		11	125											x						O	
14	1S1E-	3S1E-		B & O RR	Riverside Shops	10		185					1926			150			x				Fairly soft		D	
15	1S1E-41-316	3S1E-	1	B & O RR	Riverside Shops	13		180		132-179		179	1924	50		300				x	x			Layne - N.Y.	O	2 wells abandoned & filled in Bottom on rock. Water in white sand and gravel
16	1S1E-41-326	3S1E-	2	B & O RR	Riverside Shops	13		170		132-170			1924			168			x	x	x		Hard water	Layne - N.Y.	D	" " " "
17	1S1E-33-656	2S2E-		B & O RR	Pier E, Locust Point			165																L. P. Schultz	O	No hard rock
18		1S7W- ?	1	Balto. Paint & Color Works	150 S. Calverton Rd.													x							H	
19		1S7W- ?	2	" " "	150 S. Calverton Rd.													x							H	
20		1S7W- ?	3	" " "	150 S. Calverton Rd.														x						H	

SHEET No. 5

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1W-38-169	2S1W-		Baltimore Pearl Hominy Co.	Ft. Sharp & Howard					-50 -59			1920			25								Hoshall	O	(8 wells (rock at 65 to 85
2	Bal 9-8	3S6E-	1	Baltimore Pure Rye Dist. Co.	Sollers Pt.Rd.Dundalk		52	379					1934	(1939) 100	124	300	312	x					Good	Shannahan	A,C,D,H	
3	Bal 9-8	3S6E-	2	" " "	" " "		52	359					1934		159	325	309	x					Good	Shannahan	A,C,D,H	
4		1S1W-		Baltimore Refrigeratg & Heating Co.	426 S. Eutaw St.	8	30	304		305				30		25			x			Crys.	Bad	Miller		
5	1S1W-18-879	1S1W-		" " "	426 S. Eutaw or Barre & Eutaw	6-8	30	100		45-57		65		30-35		All 60			x	x	x	Crys.	Bad. High in CO_2	Downin	G,D	(20 wells. Water at (45-57, Rock at 65'
6	N.P. 1-626		2	Baltimore Transit Co.	Bay Shore Park Power House	6	10	634					1907	+ 3		150		x			x	Kpx	Hard	Shannahan	A,D,C,G	W 20, H 20 + B-216 Formerly United Rws.
7	N.P. 6-61			" " "	" " Pump House	8	5	743		721-743			1907	+15	68	150		x		x	x	Kpx	Hard	Shannahan	C,G,D,H	West well
8	N.P. 1-66			" " "	" " Power House	8	6	402½		402½			1907	+ 3		100				x	x	Kpx	Iron	Shannahan	G,D	
9			1	" " "	" " "	8	6	339½		339½			1905	6	35	66		x				Kpx	Iron	Shannahan	G,H,C	East well
10	Bal 3-368	5S6E-		" " "	Sollers, Bear Creek	8	10	226		200-226			1903			110					x	Kpx	Hard	Rust or Shannahan	G,D,H	A = 226, A = 157, B = 226
11	Bal 3-368	5S6E-		" " "	Bear Creek Power House	8	10	287		284-287	149-159		1903	16		50		x		x	x	Kpx	Hard	Shannahan or Downin	G,D,H	A = 287, B = 287
12	1S1W-27-764	2S1W-		Baltimore Tube Co.	1301 Wicomico			40-80					1924		Dry				x					Hoshall	D	(Rock at 40', Div. of (Revere Copper & Brass Co.
13	1S1W-27-764	2S1W-		" " "	" "			40-80					1924		Dry				x					Hoshall	D	
14	1S1W-27-764	2S1W-		" " "	" "			40-80					1924		Dry				x					Hoshall	D	
15	1S1W-27-764	2S1W-		" " "	" "			40-80					1924		Dry				x					Hoshall	D	

SHEET No. 6

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Basement Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-12-615	1S1E-		Bartholomay Brew. Co.	Central & Cough	8	15	320								None			x			Kpx			F,D,G	(Well stopped in (quicksand
2	1N1W-48-526	3N1W-		Bartlett, Edw. L.	Mallory Lane & Oak St.	6	270	300		28										x		Crys.			D	
3		3N1W-		Bartlett, N.	Charles & 40th	6"	220	300					1895	28								Crys.		O'Donovan	G	
4		5S6E-		Bartlett & Hayward	Turners Station	8	12	550		530-550			1915	15		200		x				Kpx	Boiler use	Shannahan	C,G	(Property now belongs to (Cons.Gas & Elec.Co.
5		5S6E-		" "	" "	8	12	550		530-550			1915	20		200						Kpx	" "	"	G	(See " " " " wells One of these must still be in use
6	1S1E-56-146	3S3E-		Baugh Chemical Co.	Clinton & Werten St.	8	10	245		233	150		1908	18	82	200	84	x			x	Kpx	Originally very good Now high in Cl and	"	G,A,C,D	150' strata cased off. #4 bldg.
7	Bal. 8-75	3S3E-		" " "	" " "	8	8	171					1909		70.5		50	x		x	x		acid " "	"	D	(Acid plant. Probably (other abandoned wells.
8		3S3E-		" " "	" " "			237					1915	21.5										"	C	(This may be in use (rather than one of 2 (above
9	1N1E-83-65	1N2E-	2	Bauernschmidt Brew.	Gay & E. Federal Sts.		100	400								25						Crys.			G,D,F	D. Bull. # 80
10	1N1E-83-65	1N2E-	1	" "	" " "		100	315								31						Crys.			G,D,F	D. Bull. # 80
11	1S1E-2-111	1S1E		" "	N.W. cor. Hillen & Forest	8		315																	D	Baltimore Co. Report 302
12				Battle Park	North Point Rd.																					
13	1S1E-21-693	2S1E-		Beacham & Bros.	Foot of Warren St.	$1\frac{1}{2}$	10	58						18		Fair						Q			G,F,D	From Darton Report Not verified in 1910
14	1N1E-91-177	1N1E-		Belvedere Hotel	Charles & Chase			1105											x						D	40' decomposed rock Rest in hard rock
15		1S1E-		Bennett Potteries	Canton & Central	8	10	50	50	50				27		Large						Q	Good		G	
16		1S1E-		" "	" "	8		45												x	x				D,F,G	7 wells
17	Bal 6-89			Dr. Benson	Overlea	6		104					1926			8								Hoshall	D	
18	1S1E-13-615	1S4E-		Berderine, Geo.	Eastern & Shell Rd.	6		225								Dry								Hoshall	D	Stopped in red clay

SHEET No. 7

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Basement Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S7E-	1	Bethlehem Steel Co.	Blast Furnace Wells														x						A	Abandoned 1902 and later filled with cement
2		6S7E-	2	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
3		6S7E-	3	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
4		6S7E-	4	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
5		6S7E-	5	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
6		6S7E-	6	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
7		6S7E-	7	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
8		6S7E-	8	Bethlehem Steel Co.	Blast Furnace Wells			163								37			x						A	Filled with cement
9		6S7E-	9	Bethlehem Steel Co.	Blast Furnace Wells			122								20			x						A	Filled with cement
10		6S7E-	10	Bethlehem Steel Co.	Blast Furnace Wells														x						A	" " "
11		6S7E-	11	Bethlehem Steel Co.	Blast Furnace Wells			118								85			x						A	" " "
12		6S7E-	12	Bethlehem Steel Co.	Blast Furnace Wells	$4\frac{1}{2}$		128	100					31		102									A	Changed 1917 to 286'
13		6S7E-	13	Bethlehem Steel Co.	Blast Furnace Wells	5		192	140					30		163			x						A	Plugged cement, 1917
14		6S7E-	14	Bethlehem Steel Co.	Blast Furnace Wells	4		135	123					31		175									A	
15		6S7E-	15	Bethlehem Steel Co.	Blast Furnace Wells	5		270	163					24		163			x						A	Plugged brick
16		6S7E-	16	Bethlehem Steel Co.	Blast Furnace Wells	5		208	158				1901	31		100									A	Changed 1902
17		6S7E-	17	Bethlehem Steel Co.	Blast Furnace Wells	5		202	145				1901	29		163			x						A	
18		6S7E-	18	Bethlehem Steel Co.	Blast Furnace Wells	5		145	129				1913												A	
19		6S7E-	19	Bethlehem Steel Co.	Blast Furnace Wells	6		502					1909	2		364									A	
20		6S7E-	20	Bethlehem Steel Co.	Blast Furnace Wells	6		199	192				1916											Shannahan	A	
21		6S7E-	21	Bethlehem Steel Co.	Blast Furnace Wells	5		289	199				1917											Shannahan	A	
22		6S7E-	4	Bethlehem Steel Co.	Blast Furnace Wells	8		511	432				1923										(See No 4 A L below)	Shannahan	A	Drilled 278 in 1906 S.H. = 40'. Drilled 509 in 1909 S.H. = 4' Drilled 5011 in 1923

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S7E-	1	Bethlehem Steel Co.	Blast Furnace Wells		AL	278							(1940) 129		(1940) 58	x					(1924) Cl - 7 (1937) 7	Shannahan	A,C,H	
2		"	2	" " "	" " "		AL	284					1917				92	x					(1935) Cl - 10 (1940) 14	"	A,C,H	
3		"	4	" " "	" " "	10 4½		502 or 513	500	513			1909	4	(1942) 203	(1937) 416	(1942) 230	x					(1937) Cl - 5 (1942) 6.5	"	A,C,H	Repaired and deepened three times
4		"	5	" " "	" " "		AL	508					1920				82	x						"	A,C,H	
5		"	7	" " "	" " "		AL	280					1918		(1942) 128		(1940) 128	x					(1937) Cl - 3.5 (1940) 14.0	"	A,C,H	Repaired in 1923
6		"	8	" " "	" " "		AL	275							(1942) 140		(1940) 110	x					(1937) Cl - 3 (1940) 10	"	A,C,H	(Drilled 1918, deepened (to 275 later on ac- (count of salt
7		"	1FH	" " "	" " "		DW	538		538	508		1932	50	(1942) 108	(1937) 613	(1942) 540	x		x			(1937) Cl - 6 (1940) 6	"	A,C,H	
8		"	2FH	" " "	" " "	14 7	DW	291	261	291			1940	135	136		480	x						"	A,C,H	
9			?	" " "	" " "			224					1920											"	A,C,H	This well reported by Shannahan but not by Bethlehem Steel Co.
10		"	1MY	" " "	Mould Yard			655					1938	(1938) 97	(1942) 128	(1938) 601	(1939) 588	x					(1938) Cl - 8 (1940) 7.5	"	A,C,H	

SHEET No. 8

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S7E-	1	Bethlehem Steel Co.	Benzoil Boilers			264					1918	(1930) 97	(1942) 136	(1937) 102	(1942) 72	x			x		Chlorides (1937) 6 (1940) 8	Shannahan	A,C,H	Air lift
2		6S7E-	2	Bethlehem Steel Co.	Benzoil Boilers			265					1918	(1930) 97	(1942) 115	(1937) 112	(1942) 69	x			x		3 8	Shannahan	A,C,H	Air lift
3		6S7E-	1	Bethlehem Steel Co.	Open Hearth			209							78		90	x					Cl - 20		A,C,B	
4		6S7E-	2	Bethlehem Steel Co.	Open Hearth			216							79		106	x					Cl - 25		A,C,H	
5		6S7E-	1	Bethlehem Steel Co.	Shipyard Boiler House			283											x						A	Plugged
6		6S7E-	2	Bethlehem Steel Co.	Shipyard Boiler House			300											x						A	
7		6S7E-	1	Bethlehem Steel Co.	Marine Dept.			170					1898						x						A	Plugged
8		6S7E-	2	Bethlehem Steel Co.	Marine Dept.			131					1900						x					Repaired by Shannahan on dates stated	A	Plugged
9		6S7E-	3	Bethlehem Steel Co.	Marine Dept.			200					1914						x						A	Plugged
10		6S7E-	4	Bethlehem Steel Co.	Marine Dept.			210											x						A	Plugged
11		6S7E-	5	Bethlehem Steel Co.	Marine Dept.	6		286	273				1916	42					x						A	Plugged

SHEET No. 9

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Same in 6S7E	7S7E-	1	Bethlehem Steel Co.	Coke Oven Wells			163					1913	36					x					Shannahan	A	Plugged clay 1938
2		"	2	" " "	" " "			226					1913	36					x					"	A	" " "
3		"	3	" " "	" " "			225					1913	26					x					"	A	" " "
4		"	4	" " "	" " "			170					1913	36					x					"	A	" " "
5		"	5	" " "	" " "			169					1913	28					x					"	A	" " "
6		"	6	" " "	" " "			226					1914	39					x					"	A	" " "
7		"	7	" " "	" " "			223					1914	38					x					"	A	(Plugged cement
8		"	8	" " "	" " "			176					1914	29					x					"	A	(Wooden plug 1931
9		"	9	" " "	" " "			278					1917						x					"	A	" " "
10		"	10	" " "	" " "			280					1917						x					"	Plugged Clay 1940	Plugged clay 1938
11		"	11	" " "	" " "			295					1917						x					"	A	Plugged cement 1931
12		"	12	" " "	" " "			279					1917	58					x					"	A	Plugged clay 1938
13		"	13	" " "	" " "			527					1917	20					x					"	A	Plugged clay 1938
14		"	14	" " "	" " "			227					1917						x					"	A	Plugged Cement 1931
15		"	15	" " "	" " "			266					1917	65					x					"	A	Plugged clay 1938
16		"	16	" " "	" " "			609					1917	15'										"	A	
17		"	17	" " "	" " "			223					1917						x					"	A	Plugged clay 1938
18		"	18	" " "	" " "			273					1917						x					"	A	Plugged clay 1938
19		"	19	" " "	" " "			271					1917						x					"	A	Plugged clay 1938
20		"	20	" " "	" " "			272					1917						x					"	A	Plugged clay 1938
21		"	21	" " "	" " "	5		279	253	269			1917		86		413	x						"	A	
22		"	22	" " "	" " "	5		309	299	307			1917	60			481	x						"	A	
23		"	23	" " "	" " "			274					1917						x					"	A	Plugged cement 1931
24		"	24	" " "	" " "			226					1917	65					x						A	Plugged cement 1931

SHEET No. 10

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Same in 6S7E	7S7E-	25	Bethlehem Steel Co.	Coke Oven Wells			279					1917						x					Shannahan	A H	Plugged cement 1931
2		"	26	" " "	" " "			227					1917						x					"	"	Plugged clay 1938
3		"	27	" " "	" " "			514					1917						x	x				"	"	" " "
4		"	28	" " "	" " "			503					1917		135		850	x						"	"	
5		"	29	" " "	" " "			231					1931	80					x					"	"	Plugged clay 1940
6		"	30	" " "	" " "	12 8		295	268	289			1936	88	140		418	x						"	"	
7		"	31	" " "	" " "	12 7		624	520	615	575+ 530		1939	115			505	x						"	"	Also 575 + 530'
8		"	32	" " "	" " "	14 7		302	271	303			1940	122	144			x						"	"	
9		"	1	" " "	Old Coke Ovens	5		428	241	('04) 200			1902	15		12.2			x					"	A,C	Filled cement 1914
10		"	2	" " "	" " "	5		213	179				1902	27		7.3			x					"	"	" " "
11		"	3	" " "	" " "	5		221	204				1902	20		15			x					"	"	
12		"	4	" " "	" " "	4½		424		('04) 200			1902	22		16			x					"	"	Filled cement 1914
13		"	5	" " "	" " "	6		538	179	220			1908	36		11.3			x					"	"	Filled 1939
14		"	6	" " "	" " "			233					1911						x					"	"	" "
15		"	7	" " "	" " "			223					1913	45					x					"	"	Unavailable

Line No.	Location No.	Square Location No.	Owner's No.	Owner	Address	Diam. in.	Surf. Elev. ft.	Well	Casing	Main Supply	Subordinate Supply	Abandoned Formation	Date Drilled	Static Head Original	Static Head 1940-1942	Yield Original	Yield 1940 1942	In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S8E	1	Bethlehem Steel Co.	40" Plate Mill	6		210	191	210			1929	(1939) 150	(1942) 73	(1939) 48	(1942) 184	x					Chlorides (1936) 9 (1942) 69	Sharnahan	A,G,H	S.H. =167 1940
2		"	2	" "	" "	6 4½		418	398	418			1924	(1939) 156	131	48	62	x					10 7	"	"	Drilled to 202 in 1919
3		"	3	" "	" "	6 4		421	397	421			1927	(1940) 139	126	(1937) 180	(1940) 67	x					8 63	"	"	Drilled to 201 in 1919
4	May be in 6S7E-	"	4	" "	" "	10 6		480	364	480			1927	(1936) 70	(1940) 213	(1940) 277	298		x				(1940) 7.5	"	"	Plugged 1942
5		"	5	" "	" "	6 8		438	373	438			1927	(1940) 71	(1942) 123	(1937) 177	(1942) 165	x					152 8	"	"	Changed to 286 later
6		"	6	" "	" "	8		419	362	419			1928	(1940) 145	(1942) 122	145	151	x					10 71	"	"	
7		"	7	" "	" "	10 6		655	308	355			1929	(1936) 70	(1940) 144	455	665	x				Kpx	14 12	"	"	
8		"	8	" "	" "	10 6		668	617	668			1929	(1936) 70	(1940) 144	560	525	x		x		Kpx	14 10	"	"	
9		"	1	" "	Hot Strip Mill	12		247	214	247			1937	All (1937) 70	All (1942) 155	(1938) 780	(1941) 705	x					Chlorides (1937) 12 (1942) 12	"	"	2 gravel conductors to 188'
10		"	2	" "	" "	12		336	306	336			1937	110	152	750	570	x					5 10	"	"	2 conductors to 278' 6" and 294' -2"
11		"	3	" "	" "	12		668	526	668	536 & 577		1937	103	144	666	575	x				Kpx	11 12	"	"	Also 578 and 536
12		"	4	" "	" "	12		330	300	330			1937	76	217	633	52.3	x					5 22	"	"	2 gravel conductors to 286'
13		"	5	" "	" "	12		233	213	233			1937	62	100	728	608	x					4 52	"	"	2 conductors 206 and 207'5"
14		"	6	" "	" "	12 7		680	530	675	540 & 577		1937	86	160	791	687	x				Kpx	8 14	"	"	Also 577 & 540
15		"	7	" "	" "	12 7		685	572	685	583		1937	104	290	389	360	x		x		Kpx	11 12	"	"	Also 562 & 583
16		"	8	" "	" "	12		234	220	234			1937	59	124	666	625	x					4 20	"	"	2 conductors 217'11" and 218' -4"

SHEET No. 11
Continued

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Abandoned Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
17		6S8E-	9	Bethlehem Steel Co.	Hot Strip Mill	12		335	305	335			1937	78	168	676	575	x					Chlorides (1937) 6 (1942) 190	Shannahan	A,G,H	2 conductors 283' and 279'
18		6S7E-	1	" "	Rail Mill	3		122	111							orig. 42.3			x						A	Filled with cement 1904
19		"	2	" "	" "	3		122½								42.9			x						A	Filled with cement 1904
20		"	3	" "	" "														x						A	Filled with cement 1904
21		"	4	" "	" "	3		124	118							57.5			x						A	Filled with cement 1904
22		"	5	" "	" "	3		122	110							42.3			x						A	Filled with cement 1904
23		"	6	" "	" "	3		123	115							42.3			x						A	Filled with cement 1904
24		"	7	" "	" "	3		123	115							42.3			x						A	Filled with cement 1904
25		"	8	" "	" "											42.3			x						A	Filled with cement 1904

SHEET No. 12

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940-1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S7E-	9	Bethlehem Steel Co.	Rail Mill	3	10	120	119							28.8			x						A,H	Filled with cement 1904
2		6S7E-	10	Bethlehem Steel Co.	Rail Mill		10												x						A,H	Filled with cement 1904
3		6S7E-	11	Bethlehem Steel Co.	Rail Mill		10												x						A,H	Filled with cement 1904
4		6S7E-	12	Bethlehem Steel Co.	Rail Mill	5	10	195	170							223			x						A,H	Changed 1903 Filled with clay 1938
5		6S7E-	13	Bethlehem Steel Co.	Rail Mill	3	10	112½	106					31½		23.4			x						A,H	Filled with cement 1904
6		6S7E-	14	Bethlehem Steel Co.	Rail Mill	5	10	186	169							199			x						A,H	Changed 1903 Filled with clay 1938
7		6S7E-	15	Bethlehem Steel Co.	Rail Mill	5	10	176	161							199			x						A,H	Filled with cement 1904
8		6S7E-	16	Bethlehem Steel Co.	Rail Mill	3	10	124	119							42.3			x						A,H	Filled with cement 1904
9		6S7E-	17	Bethlehem Steel Co.	Rail Mill	4½	10	133	131							91.8			x						A,H	Filled with cement 1909
10		6S7E-	18	Bethlehem Steel Co.	Rail Mill	8	10	195					1903	29		163-234			x						A,H	Filled with cement 1909
11		6S7E-	19	Bethlehem Steel Co.	Rail Mill	8	10	301	181				1905	24		328			x						A,H	Filled with cement 1909
12		6S7E-	20	Bethlehem Steel Co.	Rail Mill	6	10	207	175				1909	48		261			x						A,H	Filled with clay 1938
13		6S7E-	21	Bethlehem Steel Co.	Rail Mill	6	10	495	230				1909	5		235			x						A,H	Abandoned 1916 and later filled with clay
14		6S7E-	22	Bethlehem Steel Co.	Rail Mill	6	10	210	194				1916			240			x					Shannahan	A,H	Filled with clay 1938
15		6S7E-	23	Bethlehem Steel Co.	Rail Mill		10	496					1917						x					Shannahan	A,H	Filled with clay 1938
16		6S7E-	24	Bethlehem Steel Co.	Rail Mill		10	504					1919						x					Shannahan	A,H	Filled with clay 1938
17		6S7E-	25	Bethlehem Steel Co.	Rail Mill		10	654					1938					x		x				Shannahan	A,H	
18		6S8E-	1	Bethlehem Steel Co.	Sheet Mill	12		177	147	172			1935	(1937) 61	(1940) 84	(1937) 490	(1942) 560	x					(1936) Cl - 21.3 (1942) 550	Shannahan	A,C,H	2 gravel conductors to 128' -10"
19		6S8E-	2	Bethlehem Steel Co.	Sheet Mill	12		235	200	228			1935	(1937) 145	(1941) 143	(1937) 490	(1941) 367	x					(1936) Cl - 12.8 (1941) 370	Shannahan	A,C,H	2 gravel conductors to 194' -2"

SHEET No. 13

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940-1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S8E-	1	Bethlehem Steel Co.	Tin Mill	10 / 4½		669	659	677			1926	(1936) 72	(1942) 129	(1936) 584	(1939) 413	x		x			(1937) Cl - 9 (1942) 20	Shannahan	A,H	
2		"	2	" " "	" "	10 / 6		369	308	369	323		1926	(1939) 165	(1941) 145	(1937) 87	(1942) 460	x					(1937) Cl - 8.5 (1942) 190	"	A,H	Turbine installed 1938 2 conductors to 298'
3		"	3	" " "	" "	10 / 4½		659	636	659			1926	(1936) 71	(1942) 138	(1936) 505	(1942) 510	x					(1937) Cl - 9.5 (1942) 15	"	A,H	
4		"	4	" " "	" "	6		320	302	320			1926	(1939) 168	(1942) 159	(1937) 57	(1942) 160						(1937) Cl - 97 (1942) 245	"		
5		"	5	" " "	" "			311											x					"	A,H	Plugged
6		"	6	" " "	" "			229											x					"	A,H	Plugged
7		"	7	" " "	" "	10 / 8		373	297	373	329		1929			(1937) 90	(1939) 52		x				(1937) Cl - 27.5 (1939) 78	"	A,H	Insufficient flow. Plugged 1942. 2 conductors to 300'
8		"	8	" " "	" "	6		330	305	330			1929	(1939) 190	(1941) 184	(1937) 149	(1941) 45	x					(1937) Cl - 36 (1941) 185	"	A,H	
9		"	9	" " "	" "			234	231							(1937) 237			x				(1936) Cl - 92.3 (1938) 247	"	A,H	Plugged
10		"	10	" " "	" "			530					1942					x						"	A,H	New well
11		"	1T	" " "	" "			165					1916						x					"	A	
12		"	2T	" " "	" "			232					1916						x					"	A	
13		"	3T	" " "	" "			332					1916	27					x					"	A	
14		"	4T	" " "	" "			251					1916	17		9.4			x					"	A	
15		"	5T	" " "	" "			322					1920						x					"	A	Lost
16		"	6T	" " "	" "			177					1920						x					"	A	Lost

Line No.	Old Md.G.S. Location No.	Square Location No.	Owner's No.	Owner	Address	Diameter in.	Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940-1942	In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S8E	1-13	Bethlehem Steel Co.	Old Town Water			100											x						A	Filled cement 1902
2		"	14	" " "	" " "			200											x						A	" " "
3		"	15	" " "	" " "			200											x						A	" " "
4		"	16	" " "	" " "	5		276	161				1900	24		15			x						A	Filled cement 1905
5		"	17	" " "	" " "	5		303	167				1900	24		13			x						A	Changed 1907
6		"	18	" " "	" " "	4½		275	254				1905						x						A	Plugged cement 1916 Filled clay 1939
7		"	19	" " "	" " "	5		192	167				1908			12			x						A	" " "
8		"	20	" " "	" " "	5		283	185				1906			12			x						A	" " "
9		"	21	" " "	" " "	5		576	164				1913						x	x				Shannahan	A	" " "
10		"	22	" " "	" " "	5		288	175				1916			20			x					"	A	" " "
11		"	23	" " "	" " "			190					1916	46				x						"	A,H	
12		"	24	" " "	" " "	5		288	201				1917	68		16			x					"	A	Filled clay 1939
13		"	25	" " "	" " "	5		225	210				1917	65		20		x						"	A,H	
14		"	26	" " "	" " "			280										x						"	A,H	
15		"	27	" " "	" " "			280										x						"	A,H	
16		"	1	" " "	Town Water	6	15	224	197	217			1919	All (1939) 110	All (1942) 74	All (1937) 90	All (1942) 103	x					(1937) (1938) Cl- 38 (1942) 22.5	"	A,H	Air lift
17		"	2	" " "	" "	6	"	301	277	297			1919	116	125	118	92	x					Cl- 11.4 19.5	"	A,H	" "
18		"	3	" " "	" "	6	"	308	283	305			1919	110	120	162	67	x					Cl- 8.5 164	"	A,H	" "
19		"	4	" " "	" "	6	"	224	202	222			1919	75	77	128	89	x					Cl- 114 140	"	A,H	" "
20		"	5	" " "	" "	6	"	224	198	219			1919	81.5	122	88	83	x					Cl-10.7 63	"	A,H	" "
21		"	6	" " "	" "		"	706					1919	86	81.5	140	89	x		x			Cl-10.7 7	"	A,H	Depth now given as 290
22		"	7	" " "	" "	6	"	317	290	312			1925	106	80	170	82	x					Cl-14 75	"	A,H	Air lift

Continued next sheet

SHEET No. 15

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940-1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S8E-	8	Bethlehem Steel Co.	Town Water	6	15	226	197	219			1920	(1939) 76	(1942)	(1939) 127	(1942)	x					(1937) Cl - 14 (1942)	Shannahan	A,H	
2		"	9	" " "	" "	6	15	323	298	317			1920	111	124	112	84	x					Cl - 7 16	"	A,H	
3		"	10	" " "	" "		15	300					1936	(1937) 72	114	(1937) 985	760	x					Cl - 14 40	"	A,H	Turbine pump
4		"	11	" " "	" "	14 7	15	322	291	322								x						"	A	Turbine pump
5		5S7E-	3	" " "	" "	6		257	236	257			1926	(1940) 101	(1942) 90	(1940) 70	(1942)	x						"	A,H	Air lift
6		"	4	" " "	" "		15												x					"	A,H	Plugged
7		"	5	" " "	" "	10 4½	15	616	585	616			1935	All ('39-'40) 153	All ('42) 145	All ('35-'37) 561	All ('42) 590	x					(1937) Cl - 11 (1942) 28	"	A,H	
8		"	6	" " "	" "	6	15	440	423	440			1925	150	142	153	118	x					Cl - 8 8	"	A,H	
9		"	7	" " "	" "	6	15	610	596	610			1935	160	142	690	530	x					Cl - 14 22	"	A,H	
10		"	8	" " "	" "	10 4½	15	625	608	619			1926		153	152	122	x					Cl - 16 46	"	A,H	
11		"	9	" " "	" "		15												x					"	A,H	Plugged
12		"	10	" " "	" "	12 7	15	618	587	618			1937	119	131.5	(1938) 705	645	x					(1939) Cl - 8 11	"	A,H	
13		"	11	" " "	" "	12 7	15	456	441	520	455 & 485		1938	112		(1938) 687	480	x					Cl - 8 14	"	A,H	(Altered in 1939 from (455,485 & 520. Now (only 441 to 455
14		"	12	" " "	" "		15	615			555							x						"	A,H	
15				" " "	Sparrows Point	4	10	98								Orig. 20									G,F	(Unverified by Md. (Geol. Survey in 1910
16				" " "	" "	4 6	10	125								100-200						40 wells			G,F	(All data from Darton's (Bull. No. 90
17				" " "	" "		10	194		175-194	117-140					200									G,F	(These wells very (likely are the same
18				" " "	" "	4	10	210			185-204														G,F	(as some of the old (wells listed under (Bethlehem Steel Co.

SHEET No. 15

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
19				Bethlehem Steel Co.	Sparrows Point	8	10	302			285–298														G,P	Probably listed under Bethlehem Steel Co.
20				" " "	" "		10	420		282–291															G,F	
21				" " "	" "		10	495																	G,F	
22				" " "	Sparrows Point Lumber Co.	4		98						Flows		20							Strong iron		G,P	2 wells. Probably same as 7th well above
23				" " "	Sparrows Point Store Co.			168					1900	10										Shannahan	F,C	

SHEET No. 16

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1				Bethlehem Repair Yds.	Key Highway																					
2		4S3E-		Bethlehem Fairfield Shipbuilding	Fairfield														x							
3	1N1W-18-523	5N1W-		Black, Duncan	Springlake Way & St. Dunstans Rd.	6		102					1929	30		60								C. Hoshall	D	
4	Bal 5-4337			Blake	Lake Sta.								1897			Dry ?				x				O'Donovan	D	W = 320, B = 82
5	1S1E-13-732	1S2E-		Bohemian Church	Eastern Ave. & Bethel	5'	15	22		45–50			1898	18		Many			x			Q			G,D	
6	1S1E-23-314	2S2E-		Booth Packing Co.	Wolfe & Lancaster	10½	5	96						18		1						Q		C. Miller	G,D,E	
7	1S1E-23-329	2S2E-		" " "	" "	6		94					1884	12		1000									G,D	
8	1S1E-23-329	2S2E-		" " "	Ft. Washington St.	10½		96						4		200									F,D	
9	1S1E-23-343	2S2E-		Boyle, John & Co.	Thames & Wolfe	3	5	142				142	1884	4		200				x	x	Kpx			G,D	Branch of Metal Package Corp.
10	1N1E-82-698	1N1E-		Branzinger, Mr.	Oliver & Dallas	4½	80	321	135	-29			1889	29		40			x			Crys.		C. Miller	G,D	
11	Bal 9-639			Brehm, H. A.	Prospect Park	4	40	136		136			1907	20		25–30						Kpx	Soft	Downin	G,D	Nr. Back River
12	1N1E-65-994	2N3E-		Brehms Brewery	Belair Rd.	8	140	1500		700–800						13					x	Crys.		Harper	G,E,D	(Plugged to -800' (Rock at 55 feet
13		2N3E-		" "	" "			1300								Dry									G,F,O	
14	1N1E-26-88	4N3E-		Bridenstein, A.	Lauraville	3	250	38		35–35			1904			10				x		Crys.	Excellent	Balto.A.W.Co.	G,D	
15		5S2E-		Brooklyn Chem. Wks.	9th & Chart Ave.			300±					1940			100	100	x					Good	Shannahan		(Shannahan has complete information
16				Brooks, Dr. Chas. H.	Brooklyn	4	60	85		85			1906	20		8–9							Hard	J.W. Craig		
17	1S1E-32-582	2S1E-		Buck Glass Co.	Lawrence & Fort	8		119					1923			58				x	x			C. Hoshall	E,D	
18	1S1E-32-582	2S1E-		" " "	" "	8		118					1922			55								C. Hoshall	D	Water in sand.

Line No.	Old Md.G.S. Location No.	Square Location No.	Owner's No.	Owner	Address	Diam. in.	Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	In Use	Abandon	Log Avail.	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Bal 9-836	2S5E-		(C) Camp Holabird	Camp Holabird	12		265					1930	60		250		x						Va. Mach. & Well Co.	A,C,D	H. H. = 110'
2		2S5E-	106	Camp Holabird	Camp Holabird			290					1930			260		x							A	
3		3S4E-	270	Camp Holabird	Camp Holabird	12		300					1936			450		x		x	x				A	Sand difficulties
4		3S4E-		Camp Holabird	Camp Holabird			257					1918	36	(1932) 60				x					Shannahan	C	
5		3S4E-		Camp Holabird	Camp Holabird								1918						x					Shanrahan	C	(3 wells (These are old Federal
6		3S4E-		Camp Holabird	Camp Holabird			275					1906	14					x					Shanrahan	C	(Dirt Co. wells. (There should be 9
7		3S4E-		Camp Holabird	Camp Holabird			275					1906	14					x					Shannahan	C	(old wells or 2 (additional ones of
8		3S4E-		Camp Holabird	Camp Holabird			275					1906	14					x					Shannahan	C	(which one is 60'
9	1S1E-24-291	2S2E-		Canton Box Co.	2512 Boston St.	8	5	100	96-100				1884	20		Good						Kpx	Slightly salty		G,D	
10	1S1E-35-636	2S3E-		Canton Distilleries	Clinton & 4th	8 2		235				235				Large				x	x		Very soft		D	3 wells
11	1S1E-15-696	1S3E-		Canton Ice Co.	1st & Canton	6		400					1910			75				x	x			Rust	D	
12	1S1E-36-438	2S3E-		Canton Iron & Steel Co.	4th Ave. & 2nd St.	8	15	215		215			1902	52		100						Kpx	Good		G,D	Water in coarse sand on top of iron ore bed.
13	1S1E-36-438	2S3E-		" " "	" " " "	8	15	235		235			1905	42		100						Kpx	Good		G,D	Water in small gravel
14	1S1E-36-696	2S3E-		Canton Power House Co.	10th St. & 5th Ave.	8	20	198								100				x	x	Kpx			G,P,D	Basal Potomac
15	1S1W-47-847	3S1W-		Carr-Lowry Glass Co.	Plowman & Kent			206											x			Crys.			O,D,E	(Water at 80-90' dry (below. Water milky
16	1S1W-47-736	3S1W-	1	Carr-Lowry Glass Co.	Wenburn & Cedley	6	10	400		390			1918	10		60	27	x			x	Crys.	1942 pH 7.4 Cl-400 ppm	H. F. Harr	D,H	(well abandoned. (Hard rock 70-80'
17		3S1W-	2	Carr-Lowry Glass Co.	Wenburn & Cedley	8	10	500+									28	x			x	Crys.	1942 pH 8.4 Cl-1600 ppm	H. F. Harr	H	(May only be two (wells on this property
18				Carsteirs Distillery	Highlandtown			240					1906	80										Shannahan	C	
19				Carstairs Distillery	Highlandtown			198					1906	90										Shannahan	C	
20				Car Shops	Curtis Bay			65						20		Many									F	

SHEET No. 18

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Bal 9-868	3S5E-	0	Chem. Pigment Co. (Division Glidden Co.)	6401 St. Helena Ave.		15	338								600		x		x	x		Very good	Shannahan	H,A,D	Division of Glidden Co.
2	Bal 9-868	3S5E-	2	Chem. Pigment Co.	6401 St. Helena Ave.		15	425		425	320		1938	80	95	1000		x			x			Shannahan	H,D	R.H = 200'
3		3S5E-	1	Chem. Pigment Co.	6401 St. Helena Ave.		15	330		330			1933			650		x			x		Very good	Shannahan	H	
4		3S5E-	3	Chem. Pigment Co.	6401 St. Helena Ave.		15	400±					1942			600		x			x			Shannahan	H	
5		3S5E-		Chem. Pigment Co.	6401 St. Helena Ave.																				H	2 wells abandoned and plugged with cement strainers failed
6	1S1E-42-261	3S1E-		Chesapeake Glass Co.	Ft. of Winder St.	1½	20	54								150						Q	Bad		F,G	
7	1S1E-42-261	3S1E-		Chesapeake Glass Co.	Ft. of Winder St.	1½	20	68								175						Q	Bad		F,G	Listed in F & O as wells of Chesapeake Guano Co.
8	1S1E-42-261	3S1E-		Chesapeake Glass Co.	Ft. of Winder St.	2	20	127								100						Kpx	Good		F,G	
9	1S1E-42-261	3S1E-		Chesapeake Glass Co.	Ft. of Winder St.	2	20	117								100						Kpx	Good		F,G	
10	1S1E-42-261	3S1E-		Chesapeake Glass Co.	Ft. of Winder St.	2	20	122								100						Kpx	Good		F,G	
11		3S1E-		Chesapeake Guano Co.	Woodall & Fort Ave.					These wells may include those listed under Chesapeake Glass Co. above.															D	9 wells

SHEET No. 19

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-32-921	2S1E-		Chesapeake Paper Board Co.	Key Hwy. & B & D RR Woodall & Fort	6		210 or less					1919			2-100	250 ea	4		x	x		Four in use has yielded brackish water for long time. Cl - 2600 ppm	Hoshall	A,D,E	9 or more wells. One to 210 in rock. Other wells 67 to 183' deep
2	Bal 3-333	4S7E-		Chesterwood Excursion Grounds	Bear Creek	4½		172		150-168			1903	- 3		50				x		Kpx		Shannahan	D,G,C	B = -172
3	1S1E-25-488	2S3E-		Chipman & Sons	Patapsco & Beston														x				Began to corrode boilers badly in 1907		O	Abandoned 1907
4	1S1E-25-444	2S3E-		Chipman & Sons	Lakewood & Beston	6	5	123		70-75			1905	6		150						Kpx	Storng iron		G,F,D	
5	1S1E-22-631	2S1E-		Chrome Works	1348 Block St.			72															Saline water		F,D	
6				Claremont Abatoir	Claremont	6	90	82½		82½			1903			70						Crys.		Downin	G	
7				Claremont Abatoir	Claremont	6	90	48		48			1903			12				x		Q	Bad	Downin		
8	Bal 5-5967			Clemens, A.	Towson, Md.	6		180					1894			20								D'Donovan	D	W = 395, H = 367, B = 215
9		1S1W-		Cold Storage Co.	409-411 W. Conway St.	8 6		353								100									F	50-353 ft. in rock. See Cons.Gas & Elec.Co. 3rd well same as this.
10				Community Ice Co.	6100 Belair Rd.														x						E	
11	1S1E-42-164	3S1E-		Cons. Gas & Elec. Co.	Gould & Winder St.	6		190								30							Water salty		D,E	
12	1S1E-15-781	1S1E-		Cons. Gas & Elec. Co.	Fait & Chesapeake	6		66					1894	17		65									D	Water in fine sand
13	1S1W-18-849	1S1W-		Cons. Gas & Elec. Co.	409-411 Conway	6	36	353		40-60						100			x				Salt water		A,D	Well filled in 1909 or 1911. Two nearby well 70' Rock at 50-70'
14		3S1W-		Cons. Gas & Elec. Co.	McComas Nr. Waterfront	4	20	150	148							Many			x			Kpx	Not used account of iron	Balto. A.W. Co.	F,D	
15		1S3E-		Cons. Gas & Elec. Co.	Fait Nr. Kenwood	6	40	66	40	30			1907			30			x			Q	Salty not used		G	
16		1S3E-		Cons. Gas & Elec. Co.	Fayette & 11th																				G	

SHEET No. 19
Continued

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
17				Cons. Gas & Elec. Co.	(Not determined)																					8 wells
18	Bal 3-368	5S6E-		Cons. Gas & Elec. Co.	Sollers Station	8		226					1903			110				x	x		Contained iron	Shannahan	A,C	Ownership disclaimed by Cons. Gas & Elec. Co.

(See also Bartlett Hayward Wells)

The Gas Co. claims to have nine wells in use and five abandoned but when asked for details could not verify this. They have two active and one inactive at the Gas plant, and one at Hampstead.

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-7-191	1S4E-		Continental Can Co.	Fayette Ext.& 14th St.	6	120	172		172			1907	40		50-60						Kpx	Good	Domin	G,E,D	
2		5S3E-	1	Continental Oil Co.	Fairfield Road		15	352					New Pump 1931	54.5		430			x		x			Shannahan	A,C,D	Drilled 1920 and equipped with turbines 1931. Not used now but not plugged
3		5S3E-	2	Continental Oil Co.	Fairfield Road		15	253					1931			405			x		x			Shannahan	A,C,H	
4	1S1E-85-2	5S3E-	3	Continental Oil Co.	Fairfield Road		15	351					1931		96	475			x		x			Shannahan	A,C,H	Are probably old wells Nos. 7,8 and 9
5		5S3E-	4	Continental Oil Co.	Fairfield Road	6	15	345		342	273	345	1936	67		410	400		x	x	x			Shannahan	A,C,H	Strainer collapsed and abandoned 1941
6		5S3E-	5	Continental Oil Co.	Fairfield Road	6	15	344			216 & 262	344	1936	88		650	570	x		x	x		Cl - 117 ppm pH- 4.9	Shannahan	A,C,H	
7		5S3E-	6	Continental Oil Co.	Fairfield Road		15	361		361	213		1937	94		390	150	x			x	1942	Cl - 560 ppm pH -4.8	Shannahan	A,C,H	
8		5S3E-	7	Continental Oil Co.	Fairfield Road		15	358		358	274		1937	112		750	675	x			x		Cl - 79 ppm pH - 5.0	Shannahan	A,C,H	
9		5S3E-		Continental Oil Co.	Fairfield Road	6	20	225	200	225			1916	30		80			6				Soft boiler use		A,C,H,G D	6 wells. Prudential Oil Co.'s old wells
10				Cook, James	601 Charing Cross Road, Catonsville																				E	

SHEET No. 21

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		1S1E-	5	Cooperative Ice Co.	Frederick & Balto. St.	8	10	125		40-66			1894	17		65						Crys.		Domin	G,F,D	(4 other wells abandoned (when this well drilled
2	1S1E-11-328	1S1E-		" " "	" " "	8		125					1907			Dry								Harper	D	
3	1S1E-35-393	2S3E-		Copper Works Co.	Clinton & 3rd			160								Large					x				F,D	
4	1S1E-35-393	2S3E-		" " "	" "	4		87						16		20									F,D	
5	1S1E-35-393	2S3E-		" " "	" "	4		90						16		20									F,D	
6	Bal 5-4329			Cromwell, D.M.J.	Brightside	6		206					1899			35								O'Donovan	D	W = 280, H = 255, B = 74
7	1S1E-14-	1S4E-	1	Crown Cork & Seal Co.	Eastern & Kresson	12		233		212-220	187-196 200-210	233	1939	120	135	630	500	x		x	x		pH 3.3 Cl - 82.5	Harris-Harmon	H,A,I	Rock at 233
8		1S4E-	2	" " " "	" "								1940			300 +		x			x		pH 3.7 Cl - 105	" "	H,A	
9		1S4E-	3	" " " "	" "			234		190-219			1941		125		340	x		x	x		pH 4.9 Cl - 15	" "	8,A	
10	1S1E-17-417	1S4E-		" " " "	" "			175								1000			x		x		Originally very good		D	(Gravel at bottom (may be same well.
11	1S1E-17-427	1S4E-	Old	" " " "	" "	6	60-80	204		204			1904	50		125			x		x	Kpx		Shannahan	A,C,D,G	
12		1S4E-	Old #1	" " " "	" "			224					1930	84		900	(1938) 450		x		x			"	A,C,D,G	Sealed in 1940
13		1S4E-	#2	" " " "	" "		52	379?					1934		124	450	300		x		x			"	A,C,D,G,I	Plugged 1940
14		1S4E-	#3	" " " "	" "			207					1936	117					x		x			"	A,C,D,G	Plugged 1940
15		1S3E-	#4	" " " "	" "			184					1937	125		450	150		x		x			"	A,C,D,G	Sealed 1941
16	Bal 8-8			Cullen, A. C.	Lutherville	6		83					1923			30								Harper	D	

SHEET No. 22

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1				Curtis Bay Chemical Co.	Curtis Bay	6	10–20	200–275		200–275			1915	50		77 ea.						Kpx	Soft (used for boilers & Processing		G,O	See Balto. Co. Report 299 10 wells
2	1S1E-94-75	5S2E-		Curtis Bay Light & Water Co.	South Baltimore	8		415								275			x						G,F,D	Rock at 440'
3				" " "	" "		20	440											x						G	No water
4	1S1E-94-75	5S2E-	#1	" " "	" "	8	20	416		337½	180–200		1907			300 +			x					Harper	G	30 gal. bet. 215-235. Rock at 400. Not used account of turbidity
5	1S1E-94-75	5S2E-		" " "	" "	8	20	575		300		373	1907			100			x					"	G	Rock at 373'
6	1S1E-94-75	5S2E-		" " "	" "	8	20	130		100–120	125–130		1907			200 +			x					"	G,D,F	Note: (9 wells of which (5 less than 100 (2 wells to 200 (1 well abandoned
7	1S1E-94-75	5S2E-	#5	" " "	" "	8	20	109		109	70–90		1907			175			x					"	G,D,F	
8	1S1E-94-75	5S2E-	#2	" " "	" "	8		170' 2"		100–120			1907			120			x	x				"	O,F	
9		5S2E-		" " "	" "														x					"	G	3 additional wells
10		5S2E-		Curtis Bay Water Wks	Curtis Bay	3–8		80–190						25		Many			x						F,O	(Darton reports 8 wells (some of these are (same as above
11				Curtis, J. E.	Linden Ave. N. of Highview Ave.																				E	

SHEET No. 23

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-1-641	1S1E-		(O) Darby Candy Co.	Hil'en & Front	8	15	300–					(1894-D) 1907			(Plenty D) Dry						Crys.	Unfit for use	Harper	O,G	
3	1S1E-36-324	2S3E-		Davison Acid Works	2nd & 8th Sts.	4½	20	196						26		40						Kpx			F,G,O	
2		2N1 or 2E		Darley Park Brewery																					F	
4	1S1E-36-354	2S3E-		Davison Chem. Co.	3rd & 8th Sts.	8	20	210					1905	40		50 =						Kpx	Good	Shannahan	G,O	
5				" " "	Claremont	6	90	139½		139½			1903			75						Crys.		Downin	G	
6				" " "	" "	6	90	101½		101½			1903			75						Crys.		"	G	
7	Rel 3-87	7S5E-		" " "	Curtis Bay	10	20	148		148			1901	15		40							Very hard	Shannahan	G,O	(Considerable decrease (in quantity. These two (wells at Hawkins Point
8	Hel 3-87	7S5E-		" " "	" "	10	20	160		160			1895	20		60							Very hard	"	G,O	
9				" " "	" "			240					1909	-2 *										"	C	* Above tidewater
10		6S3E-	1	" " "	" "	6	10	244	400				1913		(1938) 61		(1938) 97		x	x	x			"	A,B,C,B	(Shannahan says this is (well on hill at Dairy (Surface El. 120' and (gives static head 138'
11	C B 15-671	6S3E-	2	" " "	" "	6	10	460	429							160			x	x	x			"	A,B,C,H	
12		6S3E-	3	" " "	" "	6		430	400										x	x	x			"	A,B,C,H	(Logs for wells 1,2,3 (and 4 are identical to (their depths
13		6S3E-	4	" " "	" "	6		323	281				1919	22	22				x	x	x			"	A,B,C,H	
14		6S3E-	5	" " "	" "	6		306	289				1924	58	58				x	x	x			"	A,B,C,H	(Logs for wells 5 & 6 (are identical
15		6S3E-	6	" " "	" "	6		316	240	316								x		x	x			"	A,B,C,H	
16		6S3E-	7	" " "	" "		20	339	322	339			1928	·	(1938) 87		(1938) 140	x		x	x			"	A,B,C,H	
17		6S3E-	8	" " "	" "	16		335		290–335			1939	89		400		x		x	x			Harris-Harmar	O,A,H	Pumping level 130'

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Ft. fr. Surface Orig-inal	1940-1942	G.P.M. Orig-inal	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Inform-ation	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
18	1S1E-23-314	2W2E-		Davidson & Co.	Wolfe & Lancaster	8	5							3		Plenty							Water unfit for use		G,F,D	
19	1N1W-15-329	5N2W-		Dixon	Belvedere & Falls Rd.	6	260	56		56			1908	6		20						Crys.		Downin	G,D	
20	Gun 8-1947			Dorl, Edward	341 Milton Ave.	8		70					1931												D	
21	Gun 8-1947			Dorl, Edward	341 Milton Ave.	8		90					1931	5		Large									D	B - - 90
22	1S1E-12-848	1S1E-		Dukert & Co.	President & Fleet Sts. & Canton Ave.			90						3		Many			x			Q			F,G,D	

SHEET No. 24

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Patomac Formation	Date Drilled	Static Head ft. fr. Surface Orig-inal	1940-1942	Yield G.P.M. Orig-inal	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Inform-ation	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		2S1E-		Dunnington & Co.	Ft. of Hughes St.	4		65							6								Fair		F	
2		1N6E-	1	(E) Eastern Rolling Mills Co.	Rolling Mills Rd.			182	172			182							x	x		Kpx		Shannahan	A,I	
3		1N6E-	2	" " "	" " "	12		182½	163				1922						x			Kpx		"	A,I	Abandoned 1942
4		1N6E-	3	" " "	" " "			180-4	163				1922						x			Kpx		"	A,I	(All abandoned wells
5		1N6E-	4	" " "	" " "			167	149				1922						x			Kpx		"	A,I	(had caved in and (were delivering
6		1N6E-	5	" " "	" " "			173	141				1923						x			Kpx		"	A,I	(sand and clay. (none were sealed
7		1N6E-	6	" " "	" " "			194											x			Kpx			A,I	
8		1N6E-	7	" " "	" " "			130										x							A,I	
9		1N6E-	8	" " "	" " "			229					1928	83		200			x						A,I	
10		1N6E-	9	" " "	" " "														x						A,I	
11		1N6E-	10	" " "	" " "														x						A,I	Abandoned 1942
12		1N6E-	11	" " "	" " "			175					1928			500	150	x		x			Good	Ohio Drilling Co.	A,I	
13		1N6E-	12	" " "	" " "								1943					x						Shannahan	I	
14		1N6E-	13	" " "	" " "								1943					x						"	I	
15		1N6E-	14	" " "	" " "								1943					x						"	I	
16		1N6E-	15	" " "	" " "								1943					x						"	I	
17	Gun 8-519			Ebert, G.	101 N. Linwood Ave.			67																	D	Unfinished
18	1S1E-13-513	1S2E-		Echeles, L. & Sons	Gough Nr. Broadway	4½	20	135	135	135			1905	35		20						Kpx		Downin	G,D	
19	1S1E-13-512	1S2E-		" " "	" " "	6	20	165	130	130			1906	35		45						Kpx	Rock at 95'	"	G,D	4' strainer at 90'
20	1S1E-13-512	1S2E-		" " "	" " "	8	20	125		125			1909	35		35						Kpx		"	G,D	10' strainer at 90'
21	1S1E-13-512	1S2E-		" " "	" " "	6		90		40-80 & 90			1911	30		40-50 40-50					x			"	D	

SHEET No. 25

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-33-265	2S2E-		Ehrman, Lewis	1032-34 Haubert	8	20	128	128	128				18		45						Kpx			G,D	
2	1N1W-32-476	4N,4W-		Electric Park Amu.	Electric Park	6"	420	190		190			1898	30		75						Crys.		O'Donovan	G,D	
3	1S1E-36-616	2S3E-		Electric Ref. Co.	4th Ave. & 8th St.	10	15	129								120			x			Kpx			G,F,D	2 wells)Plant)abandoned)in 1903
4	1S1E-46-249	3S3E-		" " "		3 6	15	50-100								160 in all			x			Kpx			F,G	2 wells
5	1S1E-46-249	3S3E-		" " "		8	15	216						38		150			x			Kpx			F,G	Rock at 216
6		2S1W-		Ellicott Machine Corp.	1611 Bush St.																					Now Union Ship Building
7				Ellis Co.	East Brooklyn	6	10	325		325			1908	5		100							Hard	N. H. Milligan		
8	1S1E-12-465	1S1E-		Elmer, L. & Sons	President & Stiles		10	35 +								5-6 ea.						Q			G,D	3 wells
9		1S1E-		" " "	Central Ave. & Bank St.		10	55								Dry						Q			G	5 wells
10	1S1E-12-649	1S1E-		" " "	" " "	4½	10	60		30-60						Large				x		Q			G,D	Choked after 9 months
11		1S1E-		" " "	" " "	6	10	72		60-70			1909	15		15-20 ea						Q		Miller	G	3 wells
12	1S1E-12-649	1S1E-		" " "	" " "	4½	10	72		60-70			1909	15		15-20 ea						Q		"	G,D	3 wells

SHEET No. 26

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Gun 7-2			Elton, T. D.	Middle River Branch	6		144					1942			5							Soft	H. E. VanHon	D	
2	1S1E-11-216	1S1E-		Emerson Hotel	Calvert & Bank Lane	10	15	90		55		76	1911	35		40				x		Crys.		T. B. Harper	G,D	
3		1S6E-		Essex Laundry	Eastern Ave. Essex, Md.																				E	
4		4N3E-		Evergreen Lawn Imp. Assoc.	Hamilton Ave. Nr. Harford Rd.	6	150	654						35 gal 510		100						Crys.		Harper	G	Well reported 1 year later to yield 250.
5		4N3E-		" " "		6	180	475					1906			Dry						Crys.		"	G	
6		4N3E-		" " "		6	180	240		80			1906			36								"	G	
7	Gun 7-11	2N7E-		Eyring, J. F.	Balto., Md.			175					1941			45									D	Blased in old well
				(F)																						
8		2S3E-		Fait & Slagles	Ft. of Streeper St.	9	5	93								20						Kpx			F,G	
9		2S3E-		" "	" " "	10	5	112								Many						Kpx			F,G	
10	1S1E-25-736	2S3E-		" "	Boston Opp. Patuxent Street	6 6 6		(90 (118 (138					Before 1903			Large									F,D	(90' well abandoned (1903 3 wells
11	Bal 6-32			Farmer, W. S.	Club Hill	6		395					1897	150		35								O'Donovan	D	
12	1S1E-24-264	2S2E-		Farren & Co.	Boston & Hudson St.		5	116					1895	23		40						Kpx		Claggett & O'Donovan	F,G,D	

Line No.	Old Md. G.S. Location No.	Square Location No.	Owner's No.	Owner	Address	Diameter in.	Surf. Elev. ft.	Feet to Bottom of — Well	Casing	Main Supply	Subordinate Supply	Patapsco Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940-1942	In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	D 41-114	3S5E-		(Federal Dist. Co. - (Property now part (of Camp Holabird	Colgate Creek, Dundalk (Wells same as (Camp Holabird		100	180-200		172						300 in all 50						Kpx	Very pure		G,D	5 wells
2	D 41-111	3S5E-		" "		5	100	184-190					1906	15-20		500-Total 300						Kpx	Very good	Shannahan	G	3 wells (water occurs (in coarse (gravel at 184'
3	D 41-141	3S5E-		" "		3		60								1½							Water poor. Not used due to small supply			Formerly Colgate (?)
4		3S5E-		Federal Yeast Co.	Colgate Creek	6		160-180					1915	15					x					Shannahan	H,C	(5 wells abandoned but (not plugged. Shannahan (says all 130' deep.
5		3S5E-		" " "	" "			309					1921	24				x			x			"	H,C	
6		3S5E-	1	" " "	" "	10		378			300		1935	50				x			x			"	H,C	
7		3S5E-	2	" " "	" "	10		378			300		1936	59				x			x			"	H,C	
8		2S2E-		Ferry Landing	Locust Point		10									Many							Fine water		G,F	Darton Report not verified in 1910
9				Flood, John T.	South Balto.	2	5	65		65			1888										Hard		O	
10	1S1E-72-971	4S1E-		Floods Park	Curtis Bay					65															D	(Old Beer Garden said to (have been on property.
11		1S1E-		Flour Mills	Ft. of Smith's Wharf																		Caused boiler scale		F 3 wells	(Now U.S.I.Chem. Co. (Curtis Bay Plant. (If so location number (is wrong

SHEET No. 28

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of — Well	Casing	Main Supply	Subordinate Supply	Patapsco Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940-1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2S2E-21-345) Bal 3-561)	7S5E-		Fort Armistead	Hawkins Point	6	15-20	570		570			1898	34 to 58	50						x		Hard		D	
2	Bal 3-619	6S6E-		Fort Carroll	Patapsco River	6	5	168		200	120		1900	20		Many			x			Kpx			D,G,F	(A = 158, A = 113, B = 158 (not in use
3	Bal 3-619	6S6E-		" "	" "			247																	D,F,A	W = 10 B = -237
4	N.F. 1-593			Fort Howard				314								110									D	B = 314
5				" "			15						1938 ?	49	49		285	x						Shannahan		(Water occurs in a fine (gravel bed and rises (to -8 to -11
6				" "			12	399					1938	49	49	410	315	x					Very good	"		
7				Fort Howard School				295					1930	35		50							Cl - 30 in 1941	"		
8		3S2E-		Fort McHenry			20	145														Kpx			G,F	Darton Report not verified 1910
9	N.F. 1-32			Fort Smallwood		6		350					1929	40		50								Hoshall (?)	D	Water occurs at 280'
10	1S1E-6-383	1S3E-		Frankfort Dist.	Kresson St.		80	238					1933		93		90	x		x	x			Wash. Well & Pump	A,D	
11		1S3E-		" "	Kresson & Fayette			153 ?					1933	86	101		90	x							H,A	Well in rear of 10 N. Kresson St.
12		3S5E-		" "	Dundalk Warehouse			400±					1936	75	98	200		x					Very good 1936		A,H	
13	1S2E-41-425	3S5E-		Prensdorf & Brown	Colgate Creek	6	100	110-135					1906	8 to 11		250-300 500						Kpx		Shannahan	G,C,D	(5 wells. May now be on (property of W.Elec.Co.
14	Bal 6-836			Fritz, G. A.	Belair Rd. Overlea			110					1919			15						Kpx		Hoshall	D	W = 200 B = 90
15				(Furst Concrete (Scow Mfg. Co.	Fairfield			309					1912	9										Shannahan	C	

SHEET No. 29

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-11-776	2S1E-		(G) Gail & Ax	Charles & Barre	6	20	380								Dry						Cry.		Red Path & Potlee (O)	G,D	In Mica Gneiss
2	1S1E-1-165	1S1E-		Gardener Dairy Co.	Calvert Nr. Center		20	600								Small						Cry.		O'Donovan	O,G	O says Red Path & Potlee Rep. as 200-300' deep 1910
3	1N1W-58-313	3N1W-		Garrett, Wm. T. N.	Charles St.	6	368	342		342			1895-6	50		70				x		Crys.		O'Donovan	G,O	
4		1S3E-		Gossengee Bros.	Haven & Fairmount																				E	
5		1S2E-		Gas Works	Eastern & Patapsco																				F	
6	1S1E-16-182	1S3E-		Gengnagel, G. W.	Gough & 3rd Sts.	4½	80	196' 8"		196' 8"	34 & 120			88		Large						Kpx	Good		G,O	
7	1S1E-14-877	1S2E-		Gibbs Preserving Co.	2301 Boston St.	6 D 8	5	200-300 100					1889	10		100						Kpx			O,G	
8	1S1E-14-877	1S2E-		Gibbs Preserving Co.	2301 Boston St.	8		100					1893	10		100								O'Donovan	F,G	
9	N.P. 3-222			Gibson Island Corp.	Gibson Island, Md.	6	25	324					1929			100		x					Good	Shannahan	O	
10	N.P. 3-222			Gibson Island Corp.	Gibson Island, Md.	8	25	320					1923	18	32	130	100	x		x	x		Good	Shannahan	O,A,C	
11	Bal 7-7			Gills, John				103					1885	16		Many								Downin	O	
12		5N1 or 2W		Gilman Country School	Roland & Belvedere																				E	
13	N.P. 6-61			Gilroy, Dr.	Bay Shore Park	6		113					1911	26		15				x				Newkirk	O	
14	1N1E-38-296	4N4E-		Glenn, E. H.	3810 White Ave.	6		93½					1919											Hoshall	O	Water in rock at 93½' Seemed to be more water than test showed
15	1S1W-18-965	1S1W-		Globe Brewing Co.	Hanover & Conway	6	23-20	197		197						10						Crys.			G,F,O	In Mica Gneiss
16	1S1E-74-341	4S2E-		Globe Shipbuilding & Dry Dock Co.	Fairfield			268																	B,O	
					Continued next page																					

SHEET No. 29
Continued

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
17	Bal 5-5			Colding, C. S.	Bellona Nr. Charles	6		100' 10"		100' 10"						12						Crys.		Downin	D	
18				Goulding, E. S.																						
19	Bal 1-52			Greek Church Rectory	Elkridge			60															Hard. High iron			Estate of
20	1S1E-24-135	2S2E-		Grebb, Louis	2357 Boston St.	4½	5	106		106				16		40-50						Kpx			G,O	

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940-1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Bal 6-91			Green	Overlea	6		110					1920			10								Hoshall	D	
2		3N2W-		Green Spring Dairy	40th & Falls Rd.	8		210					1937			18								E.A.Cook & Son	D	
3				Greenwald Packing Co.	Claremont	6	80	196		180-196						130						Crys.		Dormin	G	
4				" " "	"	6	80	196		180-196						12						Crys.		"	G	
5	1S1W-24-316	2S3W-		Greenwald Abatoir	"	6		196								130				x				"	D	A 2nd well reported here yielded 12 gpm but depth unknown
6				Grienensen, Lewis	Brooklyn	4	40	55		55			1902	40									Hard	J.W.Craig		
7	1S1E-34-477	2S3E-		Griffith & Boyd	Clinton & 5th Sts.	12	5	90								Many						Kpx			G,F,D	
8	1S1E-34-477	2S3E-		" "	" " "	10	5	190								Large									G,D	
9	N.P. 7-3			Grimes, H.	Gibson Island			489					1939			Dry									D	
10	1S1E-26-494	2S3E-		Gunther, G. Brew. Co.	Toone & 3rd Sts.	8	40	197		197	60		1899	60		175						Kpx	Hard		G,E,D	Water occurs in sand and gravel & heads up to -60 Another water bed occurred at 60'
11	1S1E-26-432	2S3E-		G.B.S. Brew. Co.	O'Donnell & 3rd	10	80	225		225						) 70						Kpx			G,D	
12	1S1E-26-432	2S3E-		" " "		10	80	230		235						)						Kpx			G	
13	1S1E-26-432	2S3E-		Gunther, George Brew. Co.	" "	6	80	208		208				56		120			x			Kpx			F,G,D	Not in use. Air pump
14	1S1E-26-432	2S3E-		" " "	" "	6	80	207								50-60						Kpx		Miller	F,G,D	Air pump
15	1N1E-26-793	4N3E-		(H) Halker, Mr.	Lauraville	3		132					1904											Balto. Art. Well Co.	D	Bed Rock at 132'. No water. Top Well elev. 300' W = 345 B = 175
16	Bal 6-557			Hammerbacker, J.C.	Harford Rd.	6		170					1922			7								Hoshall	D	
17		2S1E-		Harmond Ice Co.	Ft. of Block St.		5	106											x			Q			G	(Plant closed permanently (in 1910
18		2S1W-		Hinnis Dist. Co.	Ostend & Warner		10	800		200						20									G,F	
19		2S1W-		" " "	" "	12	10	42			-6					70						Q			G,F	
20		2S1W-		" " "	" "	12	10	42			-6					70						Q			G,F	
21				Harper	Lauraville	3	300	132					1904			Dry						Crys.		Balto. Art. Well Co.	G	

SHEET No. 31

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940-1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Bal 8-91			Harper, F. J.	Overlea	6		88					1924			9								Hoshall	G,D	Water in rock
2		7S5E-		Hawkins Point				137																	F	
3	Rel 1-452			Heath, Spencer	Elkridge	6		165					1921			30								Hoshall	D	W = 220, B = 35
4				Hendler Creamery Co.	1100 E. Balto. St.																				E	
5	1S1E-13-744	1S2E-		Heise & Bruns	Caroline & Fleet	10	10	70						1					x			Q			G,D	Abandoned on account iron
6	1N1E-94-77	1N2E-		Herring, Mr.	Duncan & McElderry	6	90	62					1899			0						Crys.		Miller	G,D	All sand - no water
7	1S1E-15-696	1S3E-		Highlandtown Ice Co.	1st St. & Canton Ave.	6	80	257		257			1906			40						Kpx	Good	Dormin	G,D	
8	1S1E-15-696	1S3E-		" " "	" " "	6	80	262		262			1906			40						Kpx	"	"	D	
9	1S1E-15-696	1S3E-		" " "	Fleet St.	10		90												x					D	See cards 150-151 equals Canton Ice Co.?
10	1S1W-38-226	2S1W-		Hilgartner & Sons	Sharp & Ostend	4	10	44								Many			x			Kpx	Very bad		F,D	D.B. # 70
11				Hilton Farms Dairy	Rolling Rd. Catonsville																				E	
12	Gun 7-422			Hollywood Park		6		133					1911			60								Newkirk	D	H-10, H-133, B-133
13	Bal 5-55			Hopkins, R. B.																					D	2 wells
14	1S1E-42-414	3S1E-		Horner & Co.	Covington & Donaldson	10	10	160						10		250									G,F,D	Site now City garbage disposal plant?
15				Horn Ice Cream Co.	1116-1120 Thompson St.																				E	
16		4N3W ?		Hotel Denmore	Denmore Park		420	106' 10"		95'	35'		1911	20		50						Crys.		Hoshall	G	
17		4N3W ?		" "	" "		420	140								20						Crys.				
18	1S1E-23-387	2S2E-		(I) Ice Works	Wolfe & Fell Sts.	8		317								300				x	x				F,D	Much water at 97'
19		2S2E-		" "	" " "			157						15		300									F,D	
20	1S1W-33-197	2S3W-		Industrial School for Boys	Wilkins & Canton Aves.			775																Conlan	D	Not finished - struck rock at 28'- Rock very hard.

SHEET No. 32

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-86-74	5S3E-		Interocean Oil Co.	East Brooklyn			246																	B,O	(Now Richfield Oil (Company
2		5S3E-		" " "	" "																				B,D	
3		2S2E-		Iron Works	Broadway & Thames																				F	
				(J)																						
4	1N1W-34-4 ?	4N3W-		Jackson, E. A.	Melvale	6		156		150			1896	40		15						Crys.		O'Donovan	G,O	Bored into 150' of serpentine rock on hill W. of Melvale station
5		5N1W-		Jackson, Howard W.	Spring Lake Way																				E	
6		6N2W-		Jenkins, Ellen K.	Lake Ave. Nr. Hollins																				E	
7		5N1W-		Jenkins, Michael	Lake Ave. Nr. Charles	8	400	300		300				15		7						Crys. Kpx		Downin	G	
8	1S1E-21-629	2S1E-		Jones Paper Mill	Federal Hill		20	402		150				70		75				x		Crys.			G,F,O	Darton Report. Couldn't verify in 1910
				(K)																						
9		2N6W ?		Kernan Hospital	Forest Ave. & Windsor Mill Rd.																				E	2 wells
10	Bal 6-91			Keinginhan, Mrs.	Overlea	6		152					1922			5								Hoshall	D	
11	1S1E-16-236	1S3E-		Kimball Tyler Co. Inc	261 S. Haven	6	60	183		140-183						35-40				x		Kpx			G,D	8th bet. Gough & Pratt (Perhaps old address)
12	1S1E-1-557	1S1E-		Kingham Provision Co.	Pleasant & North	4	25	240		240			1897	12		40					x	Crys.	Bad	Downin	D,G	
13	1S1E-1-536	1S1E-		" " "	Westport 350 Holliday	6		100-					1911							x					D	A little water at 100'
14	1S1W-47-24 ?	3S1W-		Kleine Park	Westport			40																	D	32 to 30' head in winter much lower in summer

SHEET No. 33

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-21-273	2S1E-		Knickerbocker Ice Co.	York & Williams	6	10	150		150?			1901	20		50 All						Patuxant	Brackish-much iron	Downin	G,O	8 wells. Most of these filled in to 90'
2		2S1E-		Knox Net & Twine Co.	Johnson & Barney Sts.																				E	2 Wells
3	1S1W-7-965	1S1W-		Koester's Bakery	634 W. Lexington			46					1923			5								Hoshall	O	Hard rock at 46'
4	1S1E-21-457	2S1E-		Kriel Packing Co.	9-17 Henrietta Ave.			105																	O,E	3 Wells
5	1S1E-21-457	2S1E-		Kriel Packing Co.	9-17 Henrietta Ave.			526																	O,E	
6		1S3E		Kurdle, Thos. T.	5th & Eastern	4	70	110		110				40		50					x	Kpx	Good		G,D	Now Schluderberg-K
7		1S3E		Kurdle, Thos. T.	3rd & Eastern	6	70	210		192			1909	60		Large						Kpx	Good	Newkirk	G,D	Water Occurs at 192 in sand & gravel
				(L)																						
8	1S1E-14-781	1S2E-		Langrall, J. & Bros.	2115 Aliceanna St.	8	5	90		90			1904			100						Q	Soft	Shanmahan	G,O	
9	1S1E-23-416	2S2E-		Lauer & Suter	Block & Caroline	3	10	99		45& 48			1904	8		100				x	x	Q	Very Poor	Balto. A. W Co.	G,O	
10	1S1E-23-418	2S2E-		Lauer & Suter	Thames & Caroline			99													x				D	

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	ft. fr. Surface Original	1940-1942	G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-46-475	3S3E-		Lazaretto Fort Co.	10th St. & Clinton		5	220						22		Many						Kpx			G,F,D	Water also at 155 ft. Darton Rpt. Not verified 1910
2	1N1W-34-38	4N3W-		Lee, C. O.	Melvale	6		103		103				40		10				x		Crep		O'Donovan	G,D	
3	1S1W-18-436			Levy, M.S. & Sons Hat Factory	Paca & Lombard	6	55-60 40	525			-37		1911			130-200						Crys		Rust	G,D	Driller claims well will yield 200 g p.m. Rock at 80' (409 Redwood ?)
4	D. 52-728			Lewis, Chas.	St. Helena	6	20	75±								75						Kpx			G,D	
5		4S1E-		Light Street Bridge		1½		180								Flowed Many							Iron water - Corrosive		F	
6				Lober	Frederick Rd. nr. Mt. Olivet		120	360		360						15						Crys		Dourin	G	
7				Lucas & Green Ice Co.	Belvedere Ave. W of Reisterstown Road																				E	
8		1S2W-		Lipp Soap Works	Hollands St. & Calverton Rd.		80	200		200	-65					35						Crys			G,F	
9		1S2W-		Lipp Soap Works	Hollands St. & Calverton Rd.			350			65					35						Crys			F	
10	Rel 2-4			Linthicum Hgts. Co.	Linthicum	6"	147	110		110			1909	50		12							Hard		G,D	
11	Rel 2-4			Linthicum Hgts. Co.	Linthicum	6'		80-90					1909												O	
				(M)																						
12		2S1E-		Marble Works	Lee & Johnson Sts. or York Street	2½	10	60								Small						Photo-cene	Brackish		F,G	
13		2S1E-		Marble Works	Lee & Johnson Sts. or York Street	6	10	200								Small						Crys	Brackish		F,G	

SHEET No. 34 cont'd

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued																									
14	1S1E-22-229	2S1E-		Maltby Estate	Block & Albemarle		10	900								Good				x		Crys.			G,F,D	
15	1S1E-11-4[illegible]	1S1E-		Maltby Estate	Pratt & Light Sts.	12"-10"	10	100								40						Kpx			F,G,O	
16	M.P. 6-397			R. H. Marine R.R.	Rock Hall Landing	6		120					1932			40							Iron	LeCompt	D	W-20

SHEET No. 35

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev ft.	Depths from Surface to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Alternate Formation	Date Drilled	Static Head ft. fr Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Gun-7-3			Martin, Glenn L.	Middle River	4		155												x				Wash. Well & Pump	D	Test Well
2	1S1W-37-618	2S1W		Maryland Chem. Co.	Bayard - 1 Bl. E of Russell	6		180								20								Hoshall	D	In rock 18' to 180'
3	Rel 1-2983		2	Maryland Dist.	Halethorpe	10		103								55				x				Wash. Well & Pump		
4	Rel 1-2983		3	Maryland Dist.	Halethorpe	10		107								55				x				Wash. Well & Pump		
5	Rel 1-2983		5	Maryland Dist.	Halethorpe	10		125								55				x				Wash. Well & Pump		
6	Rel 1-2983		4	Maryland Dist.	Halethorpe	10		103								55				x				Wash. Well & Pump		
7	Rel 1-2983			Maryland Dist.	Halethorpe	10		45					1933	11		450								Wash. Well & Pump		W:40, H:29, B:-5
8	Rel 1-2983			Maryland Dist.	Halethorpe			90					1933			50								Wash. Well & Pump		W:70, H:50, B:-20
9		4S2E-	1	Maryland Dry Dock Co.	Fairfield		6	200					1920	70(?)				x			x		Originally very good Cl 215 ppm 1941		A,H	
10		4S2E-	2	Maryland Dry Dock Co.	Fairfield		10	262					1926	40	51		120	x		x	x		Originally very good Cl 215 ppm 1941		A,H	Date Uncertain
11	1S1E-46-741	3S3E-		Maryland Fert. Co.	Clinton & 11th St.	2½ 1½		140						8		15						Kpx			G,F,D	3 Wells
12	1S1W-46-164	3S2W-		Maryland Glass Corp.	Mt. Winans, Md.	6	20	267		238-267						Small						Crys.		Downin	G,D	Rock at 30' (Bromo Seltzer)?
13	1S1E-27-171	2S4E-		Maryland Pure Rye Dist.	O'Donnell & 11th St.	8	40	121		121				35		80						Kpx	Soft		D,G	Well S.W. of Distillery
14	1S1E-27-171	2S4E-		Maryland Pure Rye Dist.	O'Donnell & 11th St.	6	40	157		157				40		27						Kpx	Soft		D,G	Well W. of Distillery
15	1S1E-27-171	2S4E-		Maryland Pure Rye Dist.	O'Donnell & 11th St.	8	40	172		172				45		92						Kpx	Soft		D,G	Well W. of Distillery

SHEET No. 35 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev ft.	Depths from Surface to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Alternate Formation	Date Drilled	Static Head ft. fr Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued																									
16	1S1E-27-171	2S4E-		Maryland Pure Rye Dist.	O'Donnell & 11th St.	8	40	187		187				45		80						Kpx	Soft		D,G	Well W. of Boiler House
17	1N1E-27-117	4N4E-		Mason, R. B.	Lauraville	3	320	108		100-108		112	1895	50		Pump 50? 20				x	x	Crys.	Excellent	Balto.A.W.G.	G,D	E 1
18	1N1W-48-91	3N1W-		Mathews, John	Charles St. Rd.	6		205		205			1896	60								Crys.		O'Donovan	G,D	Well near Toll Gate Charles St. Rd. & Merryman Lane
19				Mattfeldt, Otto	Mt. Washington	6	260	158½		158½												Crys.		O'Donovan	G	
20	1N1E-21-536	4N1E-		McCabe, Mr.	5211 York Rd.			300					1898	30								Crys.	Charged with iron- Not used	O'Donovan	G,D	These 3 smell like
21	1N1E-21-536	4N1E-		McCabe, Mr.	5211 York Rd.			500					1898	30									Charged with iron- Not used	O'Donovan	O	the same well to
22	1N1E-21-536	4N1E-		McCabe, Mr.	5211 York Rd.			500					1898	30									Charged with iron- Not used	O'Donovan	D	me.
23	Bal 7-		27	McConnell, J. T.	Dogwood Road	6		115					1921			15								Hoshall	D	

Line No.	Old Md G.S. Location No.	Square Location No.	Owner No.	Owner	Address	Diameter in.	Surf. Elev. ft.	Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head Original	1940-1942	Yield Original	1940 1942	In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-4-52	1S2E-		McCormick & Sons	Pratt nr. Falls	8		192					1916			8								Hoshall	D	
2	1S1E-4-54	1S2E-		McCormick & Sons	Pratt nr. Falls	8		192					1916			8								Hoshall	D	
3	1S1E-24-923	2S2E-		McGrath, H. J.	Foot of Lakewood Ave.	2½	5	176		176			1889			30						Kpx	Hard	Balto.A.W.Co.	G,D	See Card 221
4	1S1E-25-477	2S3E-			Foot of Lakewood Ave.	2	5	114						2		20						Kpx			F,D	Darton Rep. See Card 106
5		2S3E-		McGrath & Co.	Foot of Lakewood Ave.																				G,D	
6	D-62-232	3S5E-		McShanes Bell Foundry	Dundalk Foundry	8		120-230						40 both		Large									G,F,D	2 Wells
7				McShanes Bell Foundry	Dundalk	8	20	120-130		290	185-220		1907	19		104						Kpx		Shanahan	G	
8	Rel 1-434			McSherry	Lawyers Hill			304					1908			17								Schultz	D	W-240, B-64
9		5S3E-		Mexican Pet Co.	1st St. & Southport Ave. E. Brooklyn																				E	
10	Bal 6-6			Meyer, Mr.	Putty Hill, Md.	6		175					1921			1								Hoshall	D	
11	1S1E-23-318	2S2E-		Miller Bros. & Co.	901 Wolfe St.	6	10	98		98			1905	25		35				x		Q	Hard	Miller	G,D	
12	C.B. 25-355			Miller Fert. Co.	Curtis Bay		32																		B,D	
13	1S1E	1S3E-	1	Monarch Rubber Co.	3522 Phila. Rd.	8		90					1937			50	25	x			x		Hard	Harr	D	Artesian Well - Apparently just on top of hard rock
14		1S4W-		Montgomery Property	Edmondson nr. Cathedral Cem.	6	200	98½		98½						3						Crys.		Downin	G	
15		4S3E-		Monumental Acid Wks.	Seawall, Fairfield	4		155						10-15		Flows?									F	
16	1S1E-6-854	1S3E-		Monumental Brewery Co.	Lombard & 7th	8		535					1910			175				x	x			Rust	D	
17	1S1E-6-817	1S3E-		Monumental Brewing Co.	Lombard & Eaton			400 ea.								350-400									D	3 Wells

SHEET No. 36 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued																									
18		1S3E		Monumental Brewing Co.	Lombard & Eaton	10	60	480	308	480			1900	80		150						Kpx	Good	Rust	G,D	
19		2S3E		Monumental Dist. Co.	O'Donnell St.			170						12		Many						Kpx			G,F	Darton-not ver. 1910
20		2S3E		Monumental Dist. Co.	O'Donnell St.			190						12		Many						Kpx			G,F	Darton-not ver. 1910
21	1N1E-28-359			Mr. Miller	3700 Glenn Ave. Glenmore	6								38		½								Hoshall		Water 45' - Hard Rock at 14'

SHEET No. 37

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Basement Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-21-537	2S1E-		Moore & Brady	Ft. of Montgomery	8	5	135		53				10		Many				x		Kpx			O,F,D	No water below 53 85-135 Ft. in rock
2	1N1E-47-633	3N4E-		Morningstar, C. A.	Franklin nr. Belair Rd	6	220	159		145			1911	62		1				x		Crys		Hoshall	G,D	Rock at 65' – Water at 145'
3	Bal 1-427-7			Murray	Lawyers Hill	6		170					1929			25								Hoshall	D	W:240, S:70
4		8N2E-		Mylander Devel. Co.	Joppa Rd & M.P.R.R.																				E	3 Wells
5				Mylander & Patz (Lwyrs) (N)	410 Morris Bldg.																					
6	1S1E-26-194	2S3E-		National Brewing Co.	3600 O'Donnell St. O'Donnell & Conklin	10	80	330		330		230	1887	75		100	45	x			x	Kpx			F,G,D	Water in rock at 330'
7	1S1E-26-194	2S3E-		National Brewing Co.	3600 O'Donnell St. O'Donnell & Conklin	10	80	230		230			1891	75	109	65	50	x			x	Kpx			F,G,D	Water occurs in sand and gravel
8	1S1E-26-194	2S3E-		National Brewing Co.	3600 O'Donnell St. O'Connell & Conklin	8	80	430	230	430			1892	90	132	90	40	x			x	Crys			F,G,D	Water occurs in rock 430
9	1S1E-26-194	2S3E-		Natinnal Brewing Co.	3600 O'Donnell St. O'Connell & Conklin	10		240								200									D	Separate cards but probably same as wells 7 and 2 above
10	1S1E-26-194	2S3E-		National Brewing Co.	3600 O'Donnell St. O'Donnell & Conklin	6		450								200									D	
11	1S1E-31-812	2S1E-		Nat'l. Enamel & Stamping Co.	1901 Light St. Light & Wells	6	35	167		167			1902	40		75				x	x	Kpx	Soft	Downin	G,O	Yeild said to be 90 in 1910
12	1S1E-31-812	2S1E-		Nat'l. Enamel & Stamping Co.		8		162					1904	40		90								Downin	D	Water occurs in bed of coarse red sand
13	Bal 6-			Neifield, Mr.	Harford Rd.	6		270					1922			3								Hoshall	D	

SHEET No. 37 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. Ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Basement Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
14	Continued Bal 6-			Neifield, Mr.	Harford Rd.	6		169					1925			30								Hoshall		
15	1S1E-47-799	3S4E-		Northern Central R.R.	Foot of 13th	16	5	165								150						Kpx			D,C,F	Darton not ver. 1910
16	1S1E-36-696	2S3E-		Northern Central R.R.	10th & 5th Ave.	8	20	197		190				50		125				x	x	Kpx	Good		D,G,F	Water at 190-197 in coarse gravel
17	1S1E-36-744	2S3E-		Northern Central R.R.	Clinton & 6th Ave.	8	5	183		183				+2		Fair						Kpx	Iron & Mag.		G,C,D	Flows 2' above tide
18	1S1E-36-744	2S3E-		Northern Central R.R.	Clinton & 6th Ave.	8	5	215		215				20		1200 130						Kpx	Fe Mg, SiO_2 & salt	Downin	G,C,D	Another water hed at 183'
19	1S1E-56-235	3S3E-		Northern Central R.R.	Foot of 6th Ave.	4	5	174								70						Kpx			G,C,D	
				Northern Central R.R.	Clinton bet. 5Th & 6th	16	5	183		183			1876									Kpx			G,C,D	Orig. flowed at +2 & had large yield. Head dropped 30' & well was abandoned on this acc't.
20	1S1E-57-515			Northern Central R.R.	#3 Elevator-Colgates	8	5	296					1907	16		70						Kpx		Shannahan	G,D,C	57-515 has 2 other water levels 185' static level 11' 220' static level 12.5'

Line No. 1	Old Md G.S. Location No. 2	Square Location No. 3	Owner's No. 4	Owner 5	Address 6	Diameter In. 7	Surf. Elev. Ft. 8	Depths from Surface in Feet to Bottom of:- Well 9	Casing 10	Main Supply 11	Subordinate Supply 12	Potomac Formation 13	Date Drilled 14	Static Head Ft. fr. Surface Original 15	1940-1942 16	Yield G.P.M. Original 17	1940-1942 18	1942 In Use 19	Abandon 20	Log Available 21	Record Sheet 22	Geologic Horizon 23	Character of Water 24	Driller 25	Sources of Information 26	Remarks 27
1	1S1E-24-622	2S2E-		Norton Tin Co.	Boston & Luzerne Sts.	12	5	50-60		50-60						35-60 each						Q			P,D,G	4 Wells-Ruined by acid overflowing tanks & saturating gr. around wells
2	1S1E-24-622	2S2E-		Norton Tin Co.	Boston & Luzerne Sts	8	5	120		120						Large						Kpx			P,D,O	
3	1N1E-93-987	1N2E-		Novak, Mr.	Washington & McElderry Fairmount Ave	5	80	84						80		40						Crys.	Muddy	Thomas	G D	Clay with gravel below. Brosius Atlas
4				Numan	Park Heights Ave.	6	400	82½		82½						15-18						Crys.		Downin	O	
5	1S1E-22-779	2S1E-		Numsen Can Co.	Jackson & West Sts.			100			60			10											P,D	Water also at 60'
6		2S1E		Numsen, Wm. & Sons	Jackson & 5th Lane		10	100		100				10		60			x			Kpx			G,D	Rep. in 1910 as dry in 1903
7		2S1E		Numsen, Wm. & Sons	Jackson & 5th Lane	6	10	114		114			1903			60			x			Kpx		Downin	G,D	Rep. 1910 as yield of 26
8	1S1E-32-116	2S1E-		Numsen, Wm. & Sons	Jackson & 5th Lane	8		100					1904	3		26			x			Kpx		Downin	G,D	
				(O)																						
9	1S1E-33-315	2S2E-		Ober, G. & Sons	Foot of Hill St.	4& 2	5	130		130			1901	10-15		30						Kpx	Good		G,D	2 Wells ?
10	1S1E-36-199	2S3E-		Orient Dist. Co.	1st St. & 3rd Ave.		20	210								65-80						Kpx			G,P,D	Darton-not ver. 1910
11	1S1E-36-199	2S3E-		Orient Dist. Co.	1st St. & 3rd Ave.		20	185								65-80						Kpx			F,G	Darton-not ver. 1910
12	1S1E-36-199	2S3E-		Orient Dist. Co.	1st St. & 3rd Ave.		20	125														Kpx	Poor		F,G	Darton-not ver. 1910
13				Otterheimer Bros.	2308-10 Frederick Ave.																				E	

SHEET No. 39

Line No. 1	Old Md G.S. Location No. 2	New Mile Square Location No. 3	Owner's No. 4	Owner 5	Address 6	Diameter In. 7	Approx Surf. Elev. Ft. 8	Depths from Surface in Feet to Bottom of:- Well 9	Casing 10	Main Supply 11	Subordinate Supply 12	Potomac Formation 13	Date Drilled 14	Static Head Ft. fr. Surface Original 15	1940-1942 16	Yield G.P.M. Original 17	1940-1942 18	1942 In Use 19	Abandon 20	Log Available 21	Record Sheet 22	Geologic Horizon 23	Character of Water 24	Driller 25	Sources of Information 26	Remarks 27
1		5S3E-	1	Pan Am. Refining Co.	East Brooklyn			400					1922						x					Shannahan	C,H,A	Each well abandoned and
2		5S3E-	2	Pan Am. Refining Co.	East Brooklyn			400					1926						x					Shannahan	C,R,A	plugged with clay as
3		5S3E-	3	Pan Am. Refining Co.	East Brooklyn			400					1933	45					x					Shannahan	C,B,A	soon as new well drilled.
4		5S3E-	4	Pan Am. Refining Co.	East Brooklyn			396					1939	104				x		x	x			Shannahan	C,B,A	Complete pumping test data available
5				Pearson, C. H. & Co.				102												x					F	
6	1S1E-7-138	1S4E-		P.B. & W. R.R.	Bay View Junction	8		82					1892	40 or 45									Hard		D	Water & white sand & Gravel
7	1S1E-6-234	1S3E-		Pa. Water & Power Co.	3913 Phila. Ave. Phila. Rd. & 8th St.	6"		395				125	1910			60		x		x	x			Hoshall	E,D	
8	1S1E-32-632	2S1E-		Piedmont & Mt. Airy	Ft. of Woodall	4	5	109		109			1905	13		Large					x	Kpx	Soft	Miller	G,D	
9				Pinehurst	Anne Arundel Co.																				C	
10	1S1E-32-521	2S1E-		Platt Corporation	Key Hwy. & Boyle	6		119½								60					x			Downin		Sand & Clay then water bearing gravel
11	1S1E-32-521	2S1E-		Platt Packing Co.	Clement & Boyle	6	5	110		100			1904	6		30-40						Kpx	Hard - Iron	Downin	G,D	Rep. by driller as 119½' deep with yeild of 60' (May be 2 Wells)
12		1N1E		Polytechnic H. S.	Guilford & North																				I D	
13		1S1E-		Potteries	Canton & Central Aves.			45								Many									F	7 Wells See Bennett Potteries
14	Bal 6-557	6N4E-		Prims, James	Harford Rd. & Taylor Ave.			140					1921			3								Hoshall	D	W-345 B-275
15		2S2E-		Proctor & Gamble		15	10	110					1938				300	x					Brackish 1942 River Water		I	
16				Prudential Oil Co.	Fairfield, Md.																					See Continental Oil Co. Wells

SHEET No. 40

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1				Public Distilling Co.	Curtis Bay																	(Now U. S. Industrial Chemical Co.)			G	19 Wells
2				Purzer, J. Frank	Club Hill, Harford Rd.	6		154								5								Hoshall	D	
				(Q)																						
3	Bal 6-836			Quivalier, Peter	Maple Ave. Overlea	6		73					1919			20						Kpx Crys.			D	W-200. B 127

SHEET No. 41

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
				(R)																						
1	1S1E-75-945	4S3E-		Rasin Fert. Co.	Fairfield			170											x						B,D	
2	1S1E-75-977	4S3E-		Rasin Fert. Co.	Fairfield			331											x						B,D	Rock at 331
3		4S3E		Rasin Fert. Co.	Fairfield	$4\frac{1}{2}$		217						5		Many			x						F	
4				Rasin Monumental Co.	Fairfield	6		350					1901	B		40							Hard	Shannahan	G	
5		3S5E-		Reid-Avery Co.	Cleveland & Chesapeake								1943					x						Shannahan	H,I	
6	C.B. 4-192			Republic Dist. Co.	Curtis Bay		10	300																	D	
7	Bal 6-41B			Rider, Harrison	Hillen Road			205					1919			5								Hoshall	D	Water in hard rock
8		1S1E-		Robins Butter Co.	112 South Street																					
9	N.P. 6-57			Robinson	Pinehurst			300		288-300			1928										Iron	Shannahan		
10		5N1W-		Roland Park School																					O	
11	1N1W-26-46	4N2W-		Roland Park Elec. & Wt.	Roland Park	6	220	180		175						100						Crys.		Downin	D,G	W.B.Clark Apt.
12	1N1W-26-46	4N2W-		Roland Park Elec. & Wt.	Roland Park	6	220	$497\frac{1}{2}$		227			1906			18						Crys.		Downin	D,G	
13	1N1W-26-46	4N2W-		Roland Park Elec. & Wt.	Roland Park	6	220	148		148				12		70						Crys.		Downin	G	
14		4N2W-		Roland Park Elec. & Wt.	Roland Park																					25 Wells

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-6-618	1S3E-		Rome Co.	Nr. Haven & Baltimore																				D	
2	1S1E-76-817	4S3E-		Royster	Fairfield	8	10	313					1919			20		x			x		Very good A-8		H,A,B, D	Water in sand & gravel 101 of 10" & 313' 8'

SHEET No.43

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
				(S)																						
1	1S1E-56-153	3S3E-		Sanford & Brooks	1st & 2nd Sts., & 11th & 12th Ave.	6	5	252		252			1909	12		300-350						Kpx		S. M. Dexter	G,O	
2		2S4W-		St. Agnes	Wilkins Avenue			800																	P	
3	Rel 1-54			St. Augustines Church	Elkridge	6		90					1933										High iron content			2 Wells. 1 condemned.
4	1S1W-8-676	1S1W-		St. Alphonse's Church	Park & Saratoga	5'	40	42		42			1900	38		55						Crys	Good Clear	C. Miller	D,G	0-35 sand 35-42 gravel
5	Rel 1-117			St. Gavriels Home	Orange Grove			260					1927			7							Hdn 12.5. Good	Hoshall	D	See All Saints Convent for 2 other wells here.
6		3S5E-		St. Helena		6		156																		
7	1S1W-21-248	2S4W-		St. Joseph's College	Irvington	6		67					1907			50									P	
8	Bal. 5-569			St. Vincent's Orph.	City Line & York Rd.	6		144					1919			60								Hoshall	D	
9		2S2or3E		Schall Packing Co.	Atlantic Wharf. Boston Street																				E	
10	1S1E-16-423	1S3E-		Schluderberg Packing Co.	Bank & 3rd Streets		90	408		160	230	230		98		150			x		x	Kpx			G,D	Rock at 230. No water
11	1S1E-16-423	1S3E-		Schluderberg Packing Co.	Bank & 3rd Streets	6	90	290		290						75-80					x	Kpx			D	216 to 408 ft. See also
12	1S1E-16-423	1S3E-		Schluderberg Packing Co.	Bank & 3rd Streets	6		310								200					x	Kpx			D	Kurdle wells.
13	1S1E-6-499	1S3E-	2	Schluderberg-Kurdle	Baltimore & Eaton			195	130				1928	76		420		x	x	x	x		Both remodeled by Lane Atlantic in 1939	Guarantee W.S W.S	P,D	Pumping Level 142'
14	1S1E-6-499	1S3E-	1	Schluderberg-Kurdle	Baltimore & Eaton	18"		195					1928			450			x	x	x			Guarantee	D,H	Gravel Wall
15	1S1E-6-499	1S3E-	Orig #1	Schluderberg-Kurdle	Baltimore & Eaton	16"		152					1922			150			x		x			Layne Co.	D,H	
16		1S3E	#3	Schluderberg-Kurdle	Baltimore & Eaton	8		272	212			267	1941	65		320	270	x		x	x			Layne Atlantic	A,H,I	Screen Length 55
17		1S3E	Orig #2	Schluderberg-Kurdle	Baltimore & Eaton			146					1922			200			x		x			Layne Co.	D,H	

SHEET No. 43 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sked	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued																									
18		1S3E	#4	Schluderberg-Kurdle	Baltimore & Eaton	8		195		170-180	146-156		1943	110		125		x		x		Kpx	Good Cl:24	Layne Atlantic	I	
19				Schmidt, Geo. J.	Highview & Stevens Ave.																				E	

SHEET No. 44

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of – Well	Casing	Main Supply	Subordinate Supply	Potomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sked	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6N1W-		Schwartz, Henry (Estate)	Gittings & Bellona Aves.	6		200					1897	29		40+						Crys.		Wm. Beck	G	
2		1S3E-		Sellmayer Packing Co.	3rd & Fleet Sts. and 527 Conklin																				E	
3	1S1W-18-592	1S1W-		Sharp & Dohme	1301 Cathedral Pratt & Howard	6	37	85				68								x	x			Downin	G,D	Rock at 68
4	1S1W-18-592	1S1W-		Sharp & Dohme	1301 Cathedral Pratt & Howard	6	36	77				77								x	x			Downin	D	
5	1S1W-18-592	1S1W-		Sharp & Dohme	Pratt & Howard	6	36	90		90						4				x	x	Crys.		Downin	D,G	Clear yellow sand at 72'
6	1S1W-18-592	1S1W-		Sharp & Dohme	Pratt & Howard	6	36	94		62		88				20				x	x	Crys.		Downin	D,G	Rock at 88'
7				Sheep Butcher's Abbatoir	Calverton		80									66						Crys.			G,P	
8	1S1E-14-478	1S2E-		Sheppard & Co.	Eastern & Chester	12	30	80						20.5		500						Q			G,F,D	Yield decreased much by 1910.
9				Simpson, W.A. (Estate of)	112 South Street																				E	Occupied by Robbins Butter Co. (-1928)
10	1S1E-44-293	3S2E-		Skinners Ship Yard	Fort McHenry	6		118					1904			Good									D	
11	1S1E-22-748	2S1E-		Skinners Ship Yard	Foot of West St.	$2\frac{1}{2}$		72								Good									F,D	

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-22-64	2S1E-		Smith Distillery				132																	F,D	Plant non-existent (D)
2	C. B.-14-892			Smith Ship Yard	Curtis Bay		11																		D	
3	N.P.-1-66			Southern Products Co.	Bodkin Creek	8		431					1908	4		10				x				Shannahan	D,C	3 Wells, 2 later than this one. One same depth, one less.
4	1S1W-37-22	2S1W-		Spring Garden Brewery Co.	Ridgely Ave. nr. B & O R. R.		20	500								Dry						Crys.			D,G,F	Rock at 30'
5	1N1W-98-969	1N1W-		Stafford Hotel	Madison & Charles	8	100	315		90			1905			15				x	x	Crys.		Rust	G,D	
6	1N1E-84-143	1N2E-		Standard Brewing Co.	Gay & Lombard Sts. E Townsend	6	120	286								15						Crys.	Iron		F,G,D	New Bismarck Brewery
7		2S4E-		Std. Dist. Products Co.	O'Donnell & 11th St.			160					1916	52							x			Shannahan	C	Property now Crown
8	1S1E-27-172	2S4E-		Std. Dist. Products Co.	O'Donnell & 11th St.	8		210				210	1919			Dry					x			Hoshall	D	Cork & Seal Co.
9	1S1E-27-172	2S4E-		Std. Dist. Products Co.				167		167			1919			60					x			Hoshall	D	
10				Std. Guano Co.	End of Curtis Bay	6	30	200	190	190-200			1915	2½		15							Soft-Satisfactory for boiler &		G	
11				Std. Guano Co.	End of Curtis Bay	6	30	200	190	190-200			1916	2½		15							processing		G	
12				Std. Guano Co.	End of Curtis Bay	6	30	200	190	190-200			1916	2½		15									G	
13	C. B.-14-311			Std. Fertilizer Co.	Curtis Bay			172																	B,D	May be same at 2 of
14	C. B.-14-313			Std. Fertilizer Co.	Curtis Bay			293																	D	next above.

SHEET No. 46

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	18	20	21	22	23	24	25	26	27
1	1S1E-26-918	2S3E-		Standard Oil Co.	1st Ave. & 8th St.	20	35	130						40		400			x			Kpx			G,F,D	Air pumps
2	1S1E-36-122	2S3E-		Standard Oil Co.	2nd A & 2nd St.	12	20	195						20		550			x		x	Kpx			G,F,D	Air pumps
3	1S1E-36-122	2S3E-		Standard Oil Co.	2nd A & 2nd St.	13	20	184								200			x		x	Kpx	Highly Acid (G)		G,D	Supply decreased from 350. Well reported highly acid in G.
4	1S1E-26-832	2S3E-		Standard Oil Co.	7th St.bet.Toone & 1st Ave.	10	40	184		170-180	140-147		1909	54		175			x			Kpx		Shanahan	G,D,C	
5	1S1E-26-816	2S3E-		Standard Oil Co.	5th St.bet. Toone & 1st Ave.	10	40	185		185						75			x			Kpx	Somewhat Acid (in G)		G,D	
6	1S1E-26-917	2S3E-		Standard Oil Co.	8th St. & 1st Ave.	B	40	190		190						25			x			Kpx			G,D	
7				Standard Oil Co.	No address	8	40	200		175-180	147-153					200			x			Kpx	Slightly acid (in G)		G	
8	1S1E-26-573	2S3E-		Standard Oil Co.	5th St. & P. B. & W. R. R.	6	40	200		180-190	150-160		1907			Small			x	x	x	Kpx		Shanahan	G,D	
9	1S1E-26-548	2S3E-		Standard Oil Co.	5th St. & P. B. & W. R. R.	6	40	200		180-190	140-150		1907						x		x	Kpx		Shanahan	G,D	
10	1S1E-26-595	2S3E-		Standard Oil Co.	Toone & 7th Sts.	10	40	213		213						100			x			Kpx	Very acid (G)		G	Formerly yielded 150
11	1S1E-27-763	2S4E-		Standard Oil Co.	W. Side of Newkirk 250' S. of Boston St.	12		224					1926	50		306			x	x	x			Layne N. Y.	D,A	Casings and
12	1S1E-27-769	2S4E-		Standard Oil Co.	750' S. of Boston St.	18		229					1929	34		336			x	x	x			Layne N. Y.	D,A	screens
13	1S1E-27-877	2S4E-		Standard Oil Co.	1250' S. of Boston St.	18		224					1929	42		504			x	x	x			Layne N. Y.	D,A	disintegrated
14	1S1E-26-548	2S3E-		Standard Oil Co.	Canton Refinery	18		224					1928	42		435			x	x	x			Layne Atl. Co.	D,A	Pumping level 110'
15		2S3E-		Standard Oil Co.	Canton			223					1936	60		300			x	x	x				A	
16		6S2E-	1	Std. Wholesale Phosphate	Curtis Ave. & Aspin	6		330½	293				1921				60	x			x			Shannahan	A	Air lift

SHEET No. 46 cont'd

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Patomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
17	Continued	6S2E-	2	Std. Wholesale Phosphate	Curtis Ave. & Aspin	6		286	264				1925				60	x			x			Shannahan	A	Air Lift
18		6S2E-	3	Std. Wholesale Phosphate	Curtis Ave. & Aspin	8"		344	296				1929	61	100		60	x		x	x			Shannahan	A	Changed to 4" in 1942
19		6S2E-	4	Std. Wholesale Phosphate	Curtis Ave. & Aspin	10		339					1941	107			200	x		x	x			Shannahan	A	Turbine Pump. Casing cemented in.
20		6S2E-	old	Std. Wholesale Phosphate	Curtis Ave. & Aspin								1920						x						A	
21		6S2E-	old	Std. Wholesale Phosphate	Curtis Ave. & Aspin								1920						x						A	
22	Bal 4			Stein	Bare Hills	6		50					1924			1								Hoshall	D	

SHEET No. 47

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Patomac formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-6-569	1S3E-		Steiner Mantel Co.	8th St. & Fairmount Ave.	3	60	120		120			1906	3		3						Kpx	Soft	Oownin	G,D	
2				Stonner, John E	Maple Ave. N. of Highway																				E	
3	1S1E-16-275	1S3E-		Stewart Dist. Co.	5th & Bank St. Dundalk Md.	4 6	75	197-202		197-202	30			54		100 ea.						Kpx	Good		G,D	5 Wells. Md. G.S. No. on card 1S1E-26-275
4	1S1E-46-741	3S3E-		Stickney Iron Co.	Clinton & 11th St.		10	175						3								Kpx			G,D	Darton-not ver. 1910
5	1S1E-46-741	3S3E-		Stickney Iron Co.	Clinton & 11th St.			226								30									D	
6	1S1E-46-741	3S3E-		Stickney Iron Co.	Clinton & 11th St.	1½		130						2		30									D	
7	1S1E-96-337	5S3E-		Stockbridge, Judge	Wagners Point			381					1908	above 20'		75				x	x			Shannahan	C,D	
				Street Railways	See: Balto. Transit Co. & Bay Shore Park																				C	Now Balto. Transit Co.
8		6S2E		Sugar Refinery	Curtis Bay	6		80						10		Many									F	
9				Sugar Refinery	Curtis Bay	4		230						10		Many									F	
10	1S1E-14-775	1S2E-		Sugar Refinery Co.	Foot of Chester St.		5	112								Large						Kpa			G,F,D	Non-existent (D)
11		1S3W		Superfine Ice Cream	47 S. Catherine St.																				E.	

Line No.	Location No.	Square Location No.	Owner's No.	Owner	Address	Diam. in.	Elev. ft.	Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Original	1940-1942	Original	1940 1942	In Use	Abandon	Log Avail.	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-46-428	3S3E-		Susquehanna Fert. Co.	1St. St. & 9th Ave.	10	10	200			120			3(G) 20(D)		Many						Kpx			G,F,D	Water also at 120 Ft.
2				Suburban Water Co.	Arlington																				W.B. Clark Rep.	7 Wells
3	B-25-332			Swift & Co.	Curtis Bay	6	30	175					1919			8								C. Hoshall	D	Water in sand
4	1S1W-18-816	1S1W-		Swift & Co.	Eutaw & Camden			105								11							H_2S		D,D	Rock at 60'
				(T)																						
5	1S1E-96-459	5S3E-		Texas Oil Co.	E. Brooklyn, Md.	6		391' 7"					1910			100				x	x			Shanahan	B,D	See Blue Print #100 & 100 a
6	Bal 7-153			Thayer Stock Farm	Windsor Mill Rd. "Woodlawn"	6		108					1911	30		80								Hoshall	D	W=415, H=385, B=307
7	1S1W-48-344	3S1W-		Thompson Chem Co.	Winder & Leadenhall	6	15 10	104	104	104			1894	30		85						Crys.	Soft		G,F,D	Water from yellow sand and gravel
8	Bal 7-159			Tippett, R. B. Lwyre	Woodlawn	6		137					1910	18		8								Downin	D	W=380, H=362, B=243
9	1S1E-32-537	2S1E-		Torsch Canning Co.	1501 Russell	6		138					1895	14		50						Kpx		Rust and Co.		
10		2S1E-		Torsch Canning Co.	Lawrence & Clement	6	5	138	138	138			1895	14		50						Kpx		Wm. Rust	G,D	Probably same well as next well above
11				Towson Ice Co.	Chesapeake & York Rd.																				E	

SHEET No. 49

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E-25-722	2S3E-		Tunis Lumber Co.	Ft. of Kenwood Ave. Ft. of Chesapeake St.	1½	5	148		148						Many						Kpx			O,F,D	
2	1S1E-24-622	2S2E-		Tyler, G. G.	Boston & Luzerne St.	4	5	225						6		Many						Kpx			F,G,D	
3	1S1E-24-388	2S2E-		Tyler, G. G.	Boston & Luzerne St.	6	5	120								40						Kpx			F,G,D	Now Bethelhem Fairfield S. D. Water in Sand & Gravel
				(U)																						
4	1S1E-75-533	4S3E-		Union Shipbldg. Co.	Fairfield	8" 6"		300-315	-100 -300				1919			100								Hoshall	B,C,D	
5		4S3E-		Union Shipbldg. Co.	Fairfield			310					1912	10										Shannahan	C	May be same as above
6	Bal 7-218			United Railways	Gwynn Oak Park	6		161								20									D	W 340, H ? A 250, B 175 Now Bolto. Transit Co. See Balto. Transit Co. Wells
7		4N2W-		United Railways Car Barn	Roland Park	6	220	386		386						5						Crys			G	
8		5S7E-		United Railways Power House	Bear Creek																				C	
9	1S1E-96-72	5S3E-		U.S.Asphalt Ref. Co.	East Brooklyn			253																	B & D	
10		5S3E-		U.S.Asphalt Ref. Co.	East Brooklyn	4	10	300	150-200	300			1915	25		70						Kpx	Soft (boiler use)		G	
11		5S3E-		U.S.Asphalt Ref. Co.	Fairfield, Md.	4	10	300	150-200	300			1915	25		70						Kpx	Soft (Boiler use)		G	
12		5S3E-		U.S.Asphalt Ref. Co.	Fairfield, Md.	4	10	300	150-200	300			1917	25		70						Kpx	Soft (Boiler use)		O	
13		5S3E-		D.S.Asphalt Ref. Co.	Fairfield, Md.	4	10	300	150-200	300			1917	25		70						Kpx	Soft (boiler use)		O	
14	Bal 3-48	7S3E-		U.S. Coast Guard	Curtis Bay		22	192							24			x		x	x				A, D	See D. S. Rev.
15	36-712	7S3E-		U.S. Coast Guard	Curtis Bay			100																	A, D	Cutter Station.

SHEET No. 49 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
16	Continued 1S1E-44-925	3S2E-		U. S. Govt. Fort McHenry	Ft. McHenry			145																	D	
17	1S1E-45-945	3S3E-		U. S. Govt. Lazaret-to L. H.	Lazaretto Point Light House	1½	5	165		165			1886	18		5			x			Kpx	Hard	J.E.Robinson	H,G,D	
18	1S1E-45-945	3S3E-		U.S.Govt. Lazaretto L. H.	Lazaretto Point Light House	8'		30											X				Very brackish and hard		H,D	
19	AA-33-327	8S2E		U.S. Ordnance Depot			50	337																	D	
20	AA-33-346	8S2E		U.S. Ordnance Depot			46	154																	D	
21	AA-33-356	8S2E		U.S. Ordnance Depot			44	106																	D	

SHEET No. 50

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S2E-	739	U.S. Ind. Alcohol Co.	(1701-1901) Patapsco Ave.			285					1917	30					x					Shannahan	A,B,C,D	Said to have formerly been Floods Amusement Park. This should be checked
2		6S2E-	740	U.S. Ind. Alcohol Co.	Curtis Bay			341½		322½			1917						x	x	x	Kpx		Shannahan	A	
3		6S2E-	741	U.S. Ind. Alcohol Co.	Curtis Bay			341					1917						x			Kpx		Shannahan		
4		6S2E-	742	U. S.Ind. Alcohol Co.	Curtis Bay			285					1917	30					x					Shannahan		
5		6S2E-	743	U.S. Ind. Alcohol Co.	Curtis Bay			285					1917	30					x					Shannahan		
6		6S2E-	744	U.S. Ind. Alcohol Co.	Curtis Bay														x							May never have been wells with these numbers
7		6S2E-	745	U.S. Ind. Alcohol Co.	Curtis Bay														x							
8		6S2E-	746	U.S. Ind. Alcohol Co.	Curtis Bay			197											x					Shannahan		
9		6S2E-	747	U.S. Ind. Alcohol Co.	Curtis Bay			297					1917	24		145			x					Shannahan		
10		6S2E-	748	U.S. Ind. Alcohol Co.	Curtis Bay			293					1917	30.5					x					Shannahan		
11		6S2E-	749	U.S. Ind. Alcohol Co.	Curtis Bay			302		295			1917	26		180			x	x	x			Shannahan		
12		6S2E-	750	U.S. Ind. Alcohol Co.	Curtis Bay			297					1917	24		201			x				Good in 1935	Shannahan		
13		6S2E-	751	U. S.Ind. Alcohol Co.	Curtis Bay			309		305			1917	26		250			x	x	x			Shannahan		
14		6S2E-	752	U.S. Ind. Alcohol Co.	Curtis Bay			306					1917	30	1934 1935				x							
15		6S2E-	1154	U.S. Ind. Alcohol Co.	Curtis Bay			431					1920						x	x	x					
16		6S2E-	1323	U.S. Ind. Alcohol Co.	Curtis Bay			357					1923	95		170		x								
17		6S2E-	1324	U.S. Ind. Alcohol Co.	Curtis Bay			295					1923	70	89	173			x	x	x					Original S.L.=59. Yield:228.
18		6S2E-	1325	U.S. Ind. Alcohol Co.	Curtis Bay			228					1923	65		250			x	x	x		Cl=80 pH 4.2, Cl fell fr. 80 to 20 fr '39 to '42 Ave Cl=65 pH 4.2			Original S.L.=62 Yield=129
19		6S2E-	1326	U.S. Ind. Alcohol Co.	Curtis Bay			327					1923	95		95		x		x	x					
20		6S2E-	1468	U.S. Ind. Alcohol Co.	Curtis Bay			367					1925	95		100			x				Cl=5 ppm through life			Plugged with cement 1940

Line No.	Old Md.G.S. Location No.	Square Location No.	Owner's No.	Owner	Address	Diam. in.	Surf. Elev. ft.	Well	Casing	Main Supply	Subordinate Supply	Patuxent Formation	Date Drilled	Original	1940-1942	Original	1940 1942	In Use	Abandon	Log Avail.	Record	Geolog. Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued																									
21		6S2E-	1469	U.S. Ind. Alcohol Co.	Curtis Bay			374					1925	95		170			x							
22		6S2E-	2540	U.S. Ind. Alcohol Co.	Curtis Bay			144					1935			700	150	x		x			Cl fell fr 240 to 21 after 2 yr. shutdown '39 to '41			Changed from turbine to air in 1941
23		6S2E-	3700	U.S. Ind. Alcohol Co.	Curtis Bay			227					1939	76		410		x		x	x		Cl:69 in '41 Cl:40 to 50 in 1942	Shannahan		
24		6S2E-	3929	U.S. Ind. Alcohol Co.	Curtis Bay			300		294			1940	106		650		x		x	x		Cl:450 in '41 to 400 in '40	Shannahan		

SHEET No. 51

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:- Well	Casing	Main Supply	Subordinate Supply	Patuxent Formation	Date Drilled	Static Head ft. fr. Surface Original	Static Head 1940-1942	Yield G.P.M. Original	Yield 1940 1942	1942 In Use	1942 Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		6S2E	4241	U.S. Ind. Alcohol Co.	Curtis Bay, Md.	10		245					1942					x		x		Kpx	p^H 5.2 Cl:3	Shannahan	I	Geyer was told that same strata as old 1468 and delivers same water
2		6S2E	1	U. S.Ind. Alcohol Co.	Curtis Bay, Md.			125					1915	17					x					Shannahan	C	Bldg. 26
3		6S2E	2	U.S. Ind. Alcohol Co.	Curtis Bay, Md.			125					1915	17					x					Shannahan	C	Bldg. 26
4		6S2E	3	U.S. Ind. Alcohol Co.	Curtis Bay, Md.			125					1915	17					x					Shannahan	C	Bldg. 26
5	1S1E-95-12	5S3E-		U.S. Ind. Chem. Co.	Fairfield, Md.			251											x						A,B,C,D	These wells probably same as some of those listed below
6	1S1E-95-12	5S3E-		U.S. Ind. Chem. Co.	Fairfield, Md.			256											x						B,D	
7		5S3E-	1694	U.S. Ind. Chem. Co.	Fairfield, Md.										1935		1935		x						A,C,H	
8		5S3E-	1695	U.S. Ind. Chem. Co.	Fairfield, Md.			265					1915		69		72		x						A,C,H	Plugged
9		5S3E-	1696	U.S. Ind. Chem. Co.	Fairfield, Md.			258					1915		76		70		x						A,C,H	Plugged
10		5S3E-	1697	U.S. Ind. Chem. Co.	Fairfield, Md.														x						A,C,H	Plugged
11		5S3E-	1698	U.S. Ind. Chem. Co.	Fairfield, Md.														x						A,C,H	
12		5S3E-	1699	U.S. Ind. Chem. Co.	Fairfield, Md.			178					1915		77		52		x						A,C,H	Plugged
13		5S3E-	1700	U.S. Ind. Chem. Co.	Fairfield, Md.														x						A,C,H	
14		5S3E-	1701	U.S. Ind. Chem. Co.	Fairfield, Md.			212					1916	47	74		83		x					Shannahan	A,C,H	
15		5S3E-	1702	U.S. Ind. Chem. Co.	Fairfield, Md.			371					1916		79		27		x			Kpx			A,C,H	
16		5S3E-	1703	U.S. Ind. Chem. Co.	Fairfield, Md.			292					1916		78		82		x						A,C,H	
17		5S3E-	1704	U.S. Ind. Chem. Co.	Fairfield, Md.		15	358					1916	37	86		84		x			Kpx		Shannahan	A,C,H	
18		5S3E-	1705	U.S. Ind. Chem. Co.	Fairfield, Md.														x						A,C,H	
19		5S3E-	5023	U.S. Ind. Chem. Co.	Fairfield, Md.	16		306		230-250			1936	65		546	500	x		x	x		Very Good	Shannahan	A,C,H	
20		5S3E-	6842	U.S. Ind. Chem. Co.	Fairfield, Md.			360½		320-360	259-282	361	1938	112		500		x		x	x	Kpx	Very Good	Shannahan	A,C,H	
21		5S3E-	7277	U.S. Ind. Chem. Co.	Fairfield, Md.			356					1941					x			x	Kpx		Shannahan	A,C,H	

SHEET No. 52

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	C.B. 33-327	7S2E-		U.S. Ordnance Depot	Curtis Bay		50	337																	B,D	
2	C.B. 33-346	7S2E-		U.S. Ordnance Depot	Curtis Bay		46	154																	D	
3	C.B. 33-356	7S2E-		U.S. Ordnance Depot	Curtis Bay		44	106																	D	
4	C.B. 33-382	7S2E-		U.S. Ordnance Depot	Curtis Bay		47																		D	
5	C.B. 33-397	7S2E-		U.S. Ordnance Depot	Curtis Bay		40																		D	
6	C.B. 34-962	7S2E-		U.S. Ordnance Depot	Curtis Bay		5																		D	
7	C.B. 34-966	7S2E-		U.S. Ordnance Depot	Curtis Bay		17	67																	D	
8	C.B. 8-14	6S4E-		U.S. Quarantine Depot	Brooklyn							420													D	
9	C.B. 8-14	6S4E-		U.S. Quarantine Depot	Brooklyn		20	136								40									D	May only be 2 wells
10		6S4E-		U.S. Quarantine Depot	Brooklyn																				A,D	
11		7S3E-		U.S. Revenue Cutter Sta.	Arundel Cove Rd.	6	20	216		216			1901	10		20								Downin	G,D	See U. S. Coast Guard
12	Rel. 3-48	7S3E		U.S. Revenue Cutter Sta.	Arundel Cove Rd.	6	15	198								150				x				Shannahan	D	
13	Bal 9-345			Unners Realty Co.	Rosedale	6		85					1910	40		10								Hoshall	D	
14	Bal 9-345			" " "	Rosedale	6		75					1910	40		10					x			Hoshall	D	
15	Bal 9-345			" " "	Rosedale	6		90					1910	40		10								Hoshall	D	
16	Bal 9-345			" " "	Rosedale	6		150					1910	70		10								Hoshall	D	
				(V)																						
17	1N1E-74-766	2N2E-		VanDerHorst Brewing Co.	Gay & North Ave.	10	120	300				36				120						Crys			F,G,D	Rock at 36' 2 Wells

SHEET No. 52 cont'd

Line No.	Old Md G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of: Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface: Original	1940-1942	Yield G.P.M.: Original	1940 1942	1942: In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Continued			(W)																						
18	1S1E-12-419	1S1E-		Wagner & Co.	Boston & Concord	6		100						7		50						Kpx			G,F,D	
19	1S1E-12-419	1S1E-		Wagner & Co.	Boston & Concord	1½		100						7		30						Kpx			G,F,D	

Line	Location No.	Location No.	Own. No.	Owner	Address	Diam. in.	Elev. ft.	Well	Casing	Main Supply	Subordinate Supply	Abandoned Formation	Date Drilled	Orig-inal	1940-1942	Orig-inal	1940 1942	In Use	Abandon	Log Avail.	Record	Geologic Horiz.	of Water	Driller	Inform-ation	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		5S3E-		Wagner, Martin, Co.	East Brooklyn	6	10	100		100			1898	7		35			x					Steele	G,C,H	How Eastern Box Co. These 4 wells abandoned from 1918 1934
2		5S3E-		Wagner, Martin, Co.	East Brooklyn	8	10	200		200			1901	7		45			x				Hard	Rust	G,H	
3		5S3E-		Wagner, Martin, Co.	East Brooklyn	6	10	170		170			1900	7		45			x				Hard	Shannahan	G,H	
4	1S1E-96-35	5S3E-		Wagner, Martin, Co.	East Brooklyn	8	10	373		373			1898			80-120			x				Hard	Shannahan	G,B,D,H	
5	1S1W-8-366	1S1W-		Walters Art Gallery	Charles & Center									67 el		200			x						0	
6	C.B. 13-68½	6S2E-		Walton, Chas.H.& Co.	Cabin Branch, C.B.	6		155 158					1919			20		x			x			C. Hoshall	A,B,D	Water in Sand
7		6S2E-		Walton, Chas.H.& Co.	Cabin Branch, C.B.	6		127					1919			36		x			x			C. Hoshall	A,H,D	Water in Sand
8		6S2E-		Walton, Chas.H.& Co.	Cabin Branch, C.B.	6		126					1919			30		x						C. Hoshall	A,H,D	Water in Sand
9		6S2E-		Walton, Chas.H.& Co.	Cabin Branch, C.B.	6	60	312					1923			110	48	x					Cl 25 - 1941	C. Hoshall	A,H,D	Water in Sand
10		1S2W-		Ward Baking Co.	2140 Edmondson Ave.																				E	
11		3S2E-		Warren Mfg. Co.	Nr. Ft. McHenry	4	5	148								50						Kpx			G,P	
12	Bal 7-71			Watkins, A. J. Realty Co.	Catonsville Knolls	6		146					1923			22.5								Hoshall	D	Public Supply. All clay. Gravel bottom Non-potable
13	1S1E-15-696	1S3E-		Water Dept.	1st & Canton	5½		63					1903	58		30								C. Miller	D	
14	1N1E-45-525	3N3E-		Weaver, C. E.	Harford Rd. nr. Webers P. B.	6	200	203		203		80	1907			2				x	x	Crys.		Roshall	D,G	
15	1N1E-45-523	3N3E-		Weaver, H. A.	Harford Rd. nr. Webers P. B.	6	200	112		112		70	1907			1				x	x	Crys.		Hoshall	0,G	
16	1S1E-17-537			Weinke Airy Co.	Eastern & 17th	6	100	420	220	420				200		40						Kpx			G,D	

SHEET No. 54

Line No.	Old Md.G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of — Well	Casing	Main Supply	Subordinate Supply	Abandoned Formation	Date Drilled	Static Head ft. fr. Surface Orig-inal	1940-1942	Yield G.P.M. Orig-inal	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Inform-ation	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1E 7-761	1S4E-		Weiskittle, A & Son	4901 Phila. Rd. 4500 E. Lombard			163					1896	4		8						K		O'Donovan	D	
2	1S1E 7-769	1S4E-		Weiskittle, A & Son	4500 E. Lombard	6½		60								Went Dry			x				Water Good			Abandoned because space needed
3	1S1E 6-866	1S3E-		Weiskittle Foundry	Lombard & 8th St.	6		263					1903							x	x			Downin	D	
4	1N1E-84-41	1N2E-		Weissners Brewery	Gay & Lanvale Sts.	8	140	1500					1907			10						Crys		Harper	G,F,D	Now American Brew.
5	1N1E-84-41	1N2E-		Weissners Brewery	Gay & Lanvale Sts.	8	140	3000					1907			15						Crys		Harper	G,D	Now American Brew.
6	1N1E-84-41	1N2E-		Weissners Brewery	Gay & Lanvale Sts.		140	600		300						200						Crys			G,D,P	Now American Brew.
7		3S4E-	1	Western Elect. Co.	Colgate Creek			301		261	301		1930	27	90	1000	800	x		x	x		Water turbid	Layne Atl.	A,H	
8		3S4E-	2	Western Elect. Co.	Colgate Creek			294		294	249		1930	27	90	650	400	x		x	x			Layne Atl.	A,H,D,E	Well repaired 1941
9	68-469			Western Md. Dairy	29th & Remington			360					1915			180			x					Roulon & Co.	D	Garage covers property (D)
10	68-469			Western Md. Dairy	29th & Remington			400					1915			220			x					Roulon & Co.	D	
11	1N1W-98-151	1N1W-		Western Md. Dairy	Linden & Dolphin Reisterstown & Belvedere			600								5								Roulon & Co.	D	3 to 35' clean white S. 2nd well 580'
12	1S1W-47-559	3S1W-		Western Md. R. R.	Westport Pump Sta. nr. Hanover & McComas	6	10	60								Small				x		Crys	Very Bad		G,D D	
13				West Arlington Imp. Co.	W. Arlington		460	197		197			1893	30		Strong						Crys			G	
14				West Arlington Imp. Co.			460	197		197			1393	30		Strong						Crys		O'Donovan	G	
15	1S1E-41-153	3S1E-		White & Middleton	Charles & Winder Sts	6	30	200					1905	6-8		Fair						Kpx	Salty - not used	Hoshall	G,D	

SHEET No. 55

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1S1W-14-984	1S3W-		Wilkins Hair Factory	Frederick Rd.	6	60	200		200			1909			35-40						Crys		Downin	G,D	Rock at 15'
2	1S1W-14-984	1S3W-		Wilkins Hair Factory		6	60	206		206			1909			4						Crys		Downin	G,D	Rock at 18
3	1S1W-14-984	1S3W-		Wilkins Hair Factory		6	60	225		225			1909			35-40						Crys		Downin	G,D	Rock at 18'
4	1S1E-6-674	1S3E-		Williamson	Cockeysville, Md. Haven & Balto. Sts.	3½		205					1904			17								Rust	E,D	
				Williams Veneer Co.	Balto. & 8th Sts.	4	60	188		186			1904	46		15						Kpx	Soft		G	
5	Bal 5-7			Willis, G. R.	Benges Balto. Co.	6		180					1909	8		40								Shannahan	D,G	
6	1S1E-23-346	2S2E-		Winebrenner Bros.	Wolfe & Thames	4	5	127		85				1		50						Kpx			G,F,D	Rock at 127'
7	1S1W-21-349	2S4W-		Wiskow, Chas.	4037 Frederick Ave.	6	200	254		200	90		1911	12		20						Crys		Hoshall	G,D	
8	1S1W-21-349	2S4W-		Wiskow, Chas.	4037 Frederick Ave.	6	200	109		80-109	30		1911	7		22½						Crys		Hoshall	G,D	
9	1S1E-32-634	2S1E-		Woodall, Wm. E. & Co.	Mariott & Allen Sts. or Ft. of Woodall St.	8	5	115	115	115			1879	6		16						Kpx	Fine Water	Miller	F,D,G	
10		3N3W-		Woode, E. J.	2429 Keyworth Ave.																				E	
11	Rel 2-43			Woodlawn Hts. Co.				500																	D	Rock at 180'
12	Rel 2-43			Woodlawn Hts. Co.				80																	D	

SHEET No. 56

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in.	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		2S2E-		Young, J. S. & Co.	Boston & Elliot			174					1896			24			x				Cl - 220 ppm at 160		G,A,D	Well in Machine shop
2	1S1E-25-448	2S3W-		Young, J. S. & Co.	2731 Boston	6	5	147	140	147			1900	18	28	60			x			Patu-xent Crys.		Miller	G,A,D	Well outside shed #6?
3	1S1E-25-448	2S2 3E		Young, J. S. & Co.	2701 Boston		5	1000		148		192	1907	*30		100			x				Cl-1268 ppm at 1000 Cl-210 ppm at 148'	Harper	G,A,D	Water at 400 & 650 Rock at 190' Well outside machine shop
4		2S3E-		Young, J. S. & Co.	2701 Boston			96								20			x				Cl - 430		G,A,D	Well in Shed #20
5		2S2E-		Young, J. S. & Co.	2701 Boston			170								90			x				Cl - 820		G,A,D	
6		2S2E-		Young, J. S. & Co.	2701 Boston			118								290			x						G,A,D	
7		2S2E-		Young, J. S. & Co.	2701 Boston			114								160			x						G,A,D	

SHEET No. 57

Line No.	Old Md. G.S. Location No.	New Mile Square Location No.	Owner's No.	Owner	Address	Diameter in	Approx. Surf. Elev. ft.	Depths from Surface in Feet to Bottom of:– Well	Casing	Main Supply	Subordinate Supply	Potomac Formation	Date Drilled	Static Head ft. fr. Surface Original	1940-1942	Yield G.P.M. Original	1940 1942	1942 In Use	Abandon	Log Available	Record Sheet	Geologic Horizon	Character of Water	Driller	Sources of Information	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		4S1E-			Light St. Bridge	1½	5	180						Flowed		Large							Iron		G,F	Darton Rep. not ver. 1910
2		2S2E-			Ferry Landing		10									Large							Good		G,F	See under Ferry Landing
3		2S3E-			Clinton & 3rd Ave.	4	20	87		87				16		20						Kpx			G	
4		2S3E-			Clinton & 3rd Ave.	4	20	90		90				16		20						Kpx			G	
5		2S3E-			Clinton & 3rd Ave.		20	160								Many						Kpx			G	
6		2S3E-			1st St. & 3rd Ave.		20	212		165						45						Kpx			G	
7		2S3E-			1st St. & 3rd Ave.			50								10 ea.						Kpx			G	6 Wells
8		2S3E-			1st St. & 3rd Ave.	8	2	114								75						Kpx			G	
9		2S3E-?			5th Ave.	8		223½								200						Kpx			G	
10		2S3E-			4th Ave. & 5th St.	8	15	225-240		225-240			1903	50		750 in all						Kpx		Shannahan	G	4 Wells
11		2S3E-			4th Ave. & 5th St.	6	15	225		225			1903	50		45						Kpx		Shannahan	G	
12		2S2E			Corner Lancaster and Caroline																				F	
13					Colgates	2	100	150		110-135			1905	8 to 11		250-300						Kpx		Shannahan	G	2 Wells
14		1 or 2S1E-			Aliceanna and West Falls Streets			112		70													Poor Water		F	Rock at 112 ft.
15		5S3E-			Wagners Point	8		381		356-381			1910			75									G	
16	D 41-144	3S5E-		Distillery	Colgate Creek	2"		150		140-150				3		35 ea.									D,F	2 Wells 0-140 Hard Red Clay Water in 10' gravel
17	1S1E -6-574	1S3E-			Eaton & Baltimore			195																	D	
18	1S1E-12-798	1S1E-			Aliceanna & W. Fall	3		112			112														D	Filled at 70

APPENDIX II

The Location Reference Table

Table XVIII is designed to accompany the list of wells in the Baltimoro Area. The owners, with addresses revised to the new street names, are arranged according to the new mile square location system. The table includes only wells lying in the coastal plain portion of the Baltimore Area and the mile aquare designations are arranged beginning at two miles and reading from left to right across the map as the printed page. The location reference table was prepared to serve in the continuing study for locating all the wells within a particular area under intensive investigation.

In carrying on field work and general studies, the selection of wells by location is an indispensable procedure. Ultimately, when the 3 x 3 successive breakdown numbers showing specifically the location of each well have been worked out, cards should be made up for each well and filed according to location. The only difficulty with the location system of filing is that many companies have wells in several mile squares and thus all the wells belonging to a single owner frequently do not appear together.

TABLE XVIII

LOCATION REFERENCE TABLE

Showing Owners having Wells in Each Mile Square

Owner		Address	No. of Wells
	2N2E		
Van Der Horst Brew. Co.		Gay & North	1
	2N3E		
Brehms Brewery		Belair Road	2
	2N7E		
Eyring, J. F.		Baltimore, Md.	1
	1N1W		
Stafford Hotel		Madison & Charles	1
Western Maryland Dairy		Linden & Dolphin	1
	1N1E		
Belvedere Hotel		Charles & Chase	1
Branzinger		Oliver & Dallas	1
Polytechnic High School		Guilford & North	1
	1N2E		
American Brewery (Formerly Weissners Brewery)		Gay & Lanvale	3

TABLE XVIII (Continued)

Owner		Address	No. of Wells
	1N2E		
Bauernschmidt Brewery		Gay & Federal	2
Herring		Duncan & McElderry	1
Novak		Washington & McElderry	1
Standard Brewing Co.		Gay & Lafayette	1
	1N6E		
Eastern Rolling Mill Co.		Rolling Mill Road	15
	1N8E		
Essex Laundry		Eastern Avenue, Essex	1
	1S3W		
Balto. Butchers' Abatoir		2601 W. Franklin St.	1
Superfine Ice Cream Co.		47 S. Catherine St.	1
Wilkins Hair Factory		Frederick Road	1
	1S2W		
American Ice Co.		Franklin & Pulaski	2
Baltimore Brewing Co.		Pratt & Frederick	1
Lipp Soap Works			2
Ward Packing Co.		2140 Edmondson Ave.	1
	1S1W		
Armour & Co.		Pratt & Eutaw	1
American Ice Co.		Schroeder & Baltimore	2
Balto. Heating & Refrig. Co.		426 S. Eutaw	21
Cold Storage Co.		409-11 W. Conway St.)	1
Cons. Gas & Elec. Co.		409-11 W. Conway St.)	
Globe Brewing Co.		Hanover & Conway	1
Koester's Bakery		534 W. Lexington	1
St. Alphonsus Church		Park & Saratoga St.	1
Sharp & Dohme		Pratt & Howard	4
Swift & Co.		Eutaw & Camden	1
Walters Art Gallery		Charles & Center	1
	1S1E		
American Building		Baltimore & South	1
Bartholomay Brew. Co.		Central & Gough	1
Bauernschmidt Brewery		Hillen & Forrest	1
Bennett Potteries		Canton & Central	8
Cooperative Ice Co.		Frederick nr. Balto. St.	6
Darby Candy Co.		Hillen & Forrest	1
Dukert & Co.		President & Fleet	3
Elmer, L. & Sons		President & Stiles	3
Elmer, L. & Sons		Central & Park	12
Emerson Hotel		Calvert & Baltimore	1
Flour Mills		Foot of Smith's Wharf	3
Guardiner Dairy Co.		Calvert nr. Center	1
Kingham Provision Co.		Pleasant & North	1
Kingham Provision Co.		Westport	1
Robins Butter Co.		112 South St.	1
Wagner & Co.		Boston & Concord	2

TABLE XVIII (Continued)

Owner	Address	No. of Wells
	1S2E	
Bohemian Church	Eastern Ave. & Bethel	1
Echels, L. & Sons	Gough nr. Broadway	4
Gas Works	Eastern & Patapsco	1
Gibbs Preserving Co.	Boston & Leakin Sts.	2
Heise & Bruns	Caroline & Fleet	1
Langrall, J. & Bro.	2115 Aliceanna St.	1
McCormick & Sons	Pratt & Falls	1
Sheppard Co.	Eastern & Chester	1
Sugar Refinery	Foot of Chester St.	1
	1S3E	
Canton Ice Co.	Highland & Fleet	1
Consol. Gas & Elec. Co.	Fait & Chesapeake	1
Consol. Gas & Elec. Co.	Fait nr. Kenwood	1
Consol. Gas & Elec. Co.	Fayette & Kresson	1
Frankfort Distillery	Fayette & Kresson	1
Gassinger Bros.	Haven & Fairmont	1
Gengnagel, G. W.	Gough & Conkling	1
Highlandtown Ice Co.	Highland & Canton (Fleet)	3
Kimball & Tyler Co.	261 S. Haven St.	1
Kurdle, Thos. J.	Eaton & Eastern	2
Monarch Rubber Co.	3522 Philadelphia Rd.	1
Monumental Brewing Co.	Lombard & Eaton	3
Pa. Water & Power Co.	3913 Philadelphia Rd.	1
Rome Co.	Nr. Haven & Baltimore	1
Schluderberg Packing Co.	Baltimore & Conkling	3
Schluderberg-Kurdle	Baltimore & Eaton	5
Sellmayer Packing Co.	527 Conkling	1
Steiner Mantel Works	Fairmount & Haven	1
Stewart Distilling Co.	Eaton & Bank	1
Water Department	Highland & Canton	1
Weiskittel Foundry	Lombard & Haven	1
Williams Veneer Co.	Haven & Baltimore	2
	Eaton & Baltimore	1
	1S4E	
Berderine, Geo.	Eastern & Shell Rd.	1
Continental Can Co.	Fayette & Newkirk	1
Crown Cork & Seal Co.	Eastern & Kresson	9
P. B. & W. R.R.	Bay View Junction	1
Weinke Airy Co.	Eastern & Quail	1
Weiskittel, A. & Sons	4901 Philadelphia Rd.	1
Weiskittel, A. & Sons	4500 E. Lombard St.	1

TABLE XVIII (Continued)

Owner		Address	No. of Wells
	1S7E		
Baltimore City		Back River Sewage Plant	1
	2S1W		
Baltimore Distilling Co.		Russell & Carey	4
Baltimore Pearl Hominy		Ft. of Sharp & Howard	8
Baltimore Tube Co.		1301 Wicomico	4
Ellicott Machine Corp.		1611 Bush	?
Hilgartner & Sons		Ostend & Sharp	1
Hannis Distillery Co.		Ostend & Warner	3
Maryland Chemical Co.		Bayard, 1 blk. E. of Russell	1
Spring Garden Brewing Co.		Ridgely Ave. nr. B & O R.R.	1
	2S1E		
American Ice Co.		Hughes & Henry	1
Baltimore City Public Well		Central & Eastern	1
Baltimore City Public Well		Aliceanna St. & W. Falls	1
Baltimore Dry Dock		Foot of West St.	1
Beachem & Bros.		Foot of Warren St.	1
Buck Glass Co.		Lawrence & Fort	2
Chesapeake Paper Board Co.		Woodall & Fort Key Highway & B & O R.R.	9 +
Chrome Works		1348 Block St.	1
Gail & Ax		Charles nr. Barre	1
Hammond Ice Co.		Foot of Block St.	1
Jones Paper Mill		Federal Hill	1
Knickerbocker Ice Co.		York & Williams	8
Knox Net & Twine Co.		Johnson & Barney	2
Kriel Packing Co.		9-17 Henrietta Ave.	4
Maltby Estate		Block & Albermarle	1
Moore & Brady		Foot of Montgomery	1
Natl. Enameling & Stamping Co.		Light & Wells	2
Numsen Can Co.		Jackson & West	1
Numsen, Wm. & Sons		Jackson & West	3
Piedmont & Mt. Airy Guano		Foot of Woodall	1
Platt Corp.		Key Highway & Boyle	1 or 2
Skinners Shipyards		Foot of West St.	1
Smith Distillery			1
Torsch Canning Co.		1501 Russell	1
Torsch Packing Co.		Lawrence & Clement	1
Woodall, Wm. E. & Co.		Mariott & Allen St.	1
		Aliceanna & West Falls	1
		Foot of Fall St.	1
	2S2E		
American Ice Co.		Wolfe & Falls Sts.	14
American Sugar Refining Co.		Foot of Woodall	1
Baltimore City Public Well		Ann nr. Lancaster	1

TABLE XVIII (Continued)

Owner	Address	No. of Wells
	2S2E	
Baltimore City Public Wells	Wolfe nr. Lancaster	1
B & O R.R. Co.	Pier 8, Locust Point	1
Booth Packing Co.	Wolfe & Lancaster	2
Boyle, John & Co.	Wolfe & Thames	1
Canton Box Co.	2512 Boston St.	1
Dixon	Wolfe & Lancaster	1
Ehrman, Lewis	1032-34 Haubert	1
Farren & Co.	Boston & Hudson	1
Ferry Landing	Locust Point	1
Grebb, Louis	2357 Boston St.	1
Ice Works	Wolfe & Fells St.	2
Iron Works	Broadway & Thames	1
Lauer & Suter	Block & Caroline	2
McGrath, H. J.	Foot of Lakewood Ave.	1
Miller Bros. & Co.	901 Wolfe St.	1
Norton Tin Co.	Boston & Luzerne Sts.	5
Ober, G. & Sons	Foot of Hill St.	2
Schall Packing Co.	Atlantic Wharf Boston St.	1
Tyler, G. C.	Boston & Luzerne St.	2
Winebrenner Bros.	Wolfe & Thames	1
Young, J. S. & Co.	2701 Boston St.	4
	Lancaster & Caroline	1
	2S3E	
Balto. Copper Works Co.	Highland & Danville	8
Balto. Smelting & Refining Co.	Eastbourne & Dean	5
Canton Distilleries	Clington & Eastbourne	3
Canton Iron & Steel Co.	Eastbourne & Baylis	2
Canton Power House Co.	Holabird & Janney Sts.	1
Chipman & Sons	Patapsco & Boston	1
Chipman & Sons	Lakewood & Boston	1
Copper Works Co.	Clinton & Conkling	3
Davison Acid Works	Cardiff & Haven	1
Davison Chemical Works	Danville & Haven	1
Electric Ref. Co.	Eastbourne & Haven	5
Fait & Slagles	Foot of Streeper St.	2
Fait & Slagles	Boston op. Patuxent St.	3
Griffith & Boyd	Clinton & Holabird	2
Gunther Brewing Co.	Toone & Conkling	1
G.B.S. Brewing Co.	O'Donell & Conkling	2
Gunther Brewing Co.	O'Donnell & Conkling	5
McGrath, H. J.	Foot of Lakewood Ave.	2
Monumental Distilling Co.	O'Donnell St.	2
National Brewing Co.	O'Donnell & Conkling	3
Northern Central R.R.	Holabird & Janney	1
Northern Central R.R.	Clinton, 1 blk. S. of Holabird	2
Orient Distilling Co.	Danville & Highland	3
Standard Oil Co.	Boston & Haven	14

TABLE XVIII (Continued)

Owner	Address	No. of Wells
3S4E		
Camp Holabird	Holabird Ave.	7
Northern Central R.R.	1 blk. W. of ft. of Newkirk	1
Western Electric Co.	Colgate Creek	2
3S5E		
Chemical & Pigment Co.	6401 St. Helena Ave.	6
Federal Distilling Co.	Colgate Creek	9
Federal Yeast Co.	Colgate Creek	8
Frankfort Distillery	Dundalk	1
Fernsdorf Brown	Colgate Creek	5
McShanes Foundry	Dundalk Foundry	1
St. Helena		1
Distillery	Colgate Creek	2
3S6E		
Baltimore Pure Rye Dist. Co.	Sellers Pt. Rd. Dundalk	2
4S1E		
Arundel Corp.	Brooklyn	1 or 2
Floods Park	Curtis Bay	1
Light St. Bridge		1
4S2E		
Globe Shipbuilding & Drydock Co.	Fairfield	1
Maryland Dry Dock Co.	Fairfield	2
4S3E		
Arundel Shipbuilding	Fairfield	1
Bethlehem Fairfield Shipbuilding	Fairfield	1
Monumental Acid Works	Seawall, Fairfield	1
Rasin Fert.	Fairfield	3
Royster Guano Co.	Fairfield	1
Union Shipbuilding Co.	Fairfield	1
4S7E		
Chesterwood Excursion Grounds	Bear Creek	1
5S2E		
Brooklyn Chem. Works	9 and Chart Ave.	1
Curtis Bay Light & Water Co.	S. Baltimore	21
5S3E		
Baltimore Chrome Works	Seawall, Fairfield	2
Continental Oil Co.	Fairfield Rd.	13
Interocean Oil Co.	E. Brooklyn	2
Mexican Pet. Co.	(E. Brooklyn (Southport & Highland Ave.	1
Pan American Refining Co.	E. Brooklyn	4
Stockbridge, Judge	Wagner Point	1
Texas Oil Co.	E. Brooklyn	1
U. S. Asphalt Ref. Co.	E. Brooklyn	5
U. S. Ind. Chem. Co.	Fairfield	17

TABLE XVIII (Continued)

Owner	Address	No. of Wells
	2S3E	
Tunis Lumber Co.	Foot of Kenwood Ave.	1
Young, J. S. & Co.	2701 Boston St.	3
	Clinton & Danville Ave.	8
	Highland & Danville Ave.	3
	Holabird Ave.	1
	Eastbourne & Eaton St.	5
	2S4E	
Amer. Radiator & Standard Sanitary Corp.	Holabird & Quail St.	1
Maryland Pure Rye Distillery	O'Donnell & Kresson	4
Standard Dist. Products Co.	O'Donnell & Kresson	3
	2S5E	
Camp Holabird	Holabird Ave.	2
	3S2W	
Maryland Glass Corp.	Mt. Winans, Md.	1
Baltimore Enamel & Novelty Co.	Ontario & B.& O R.R.	1
	3S1W	
Carr-Lowry Glass Co.	Wenburn & Cedley	3
Consol. Gas & Elec. Co.	McComas nr. Waterfront	1
Klein's Park	Westport	1
Thompson Chemical Co.	Windsor Pumping Station	1
Western Maryland R.R.	Westport Pumping Station	1
	3S1E	
B & O R.R.	Riverside Shops	4
Chesapeake Glass Co.	Foot of E. Winder St.	5
Cons. Gas & Elec. Co.	Gould & Winder	1
Horner & Co.	Covington & Donaldson	1
White & Middleton	Charles & Winder St.	1
	3S2E	
Baltimore Dry Dock Co.	Adj. Ft. McHenry	2
Fort McHenry	Locust Point	1
Skinners Shipyards	Ft. McHenry	1
U. S. Government	Ft. McHenry	1
Warren Mfg.	Nr. Ft. McHenry	1
	3S3E	
Amer. Agri. & Chem. Co.	Foot & Clinton St.	2
American Chemical Co.	Clinton & Leland	1
Baltimore Guano Co.	Clinton & Keith Ave.	4
Baugh Chemical Co.	Clinton & Werten	2
Lazaretto Fert. Co.	Clinton & Janney St.	1
Maryland Fert. Co.	Clinton & Kresson	3
Northern Central R.R.	S. of Holabird Ave.	2
Sanford & Brooks	Highland & Mertens	1
Stickney Iron Co.	Clinton & Mertens	3
Susquehanna Fert. Co.	Highland & Keith	1
U. S. Government Lazaretto, L.H.	Lazaretto Point	2

TABLE XVIII (Continued)

Owner		Address	No. of Wells
	5S3E		
Wagner, Martin Co.		Fairfield	4
Wagners Point		Fairfield	1
	5S6E		
Aluminum Ore Co.		Turners Station	1
Baltimore Transit Co.		Sollers, Bear Creek	2
Bartlett & Hayward		Turners Station	2
Cons. Gas & Elec. Co.		Sollers Station	1
	5S7E		
Bethlehem Steel Co. Wire Mill		Sparrows Point	10
United Railways Powerhouse		Bear Creek	1
	6S2E		
B & O R.R.		Coal Pier, Curtis Bay	3
Standard Wholesale Phosphate		Curtis Ave. & Aspin	6
Sugar Refinery		Curtis Bay	2
U. S. Ind. Alcohol Co.		Curtis Bay	28
Walton, Chas. H. & Co.		Cabin Branch C.B.	4
	6S3E		
B & O R.R.		Old Pier, Curtis Bay	1
Davison Chemical Co.		Curtis Bay	8
	6S4E		
U. S. Quarantine Depot		Brooklyn	3
	6S6E		
Fort Carroll		Patapsco River	2
	6S7E		
Bethlehem Steel Co.		Sparrows Point	68
	6S8E		
Bethlehem Steel Co.		Sparrows Point	61
	7S2E		
Armour Fert. Co.		Curtis Bay	2
U. S. Ordinance Depot		Curtis Bay	7
	7S3E		
U. S. Coast Guard		Curtis Bay	2
U. S. Revenue Cutter Sta.		Arundel Cove, Md.	2
	7S5E		
Davison Chem. Co.		Curtis Bay	2
Fort Armistead		Hawkins Point	1
Hawkins Point			1
	7S7E		
Bethlehem Steel Co.		Sparrows Point	39
	8S2E		
U. S. Ordinance Depot			3

APPENDIX III

WELL LOGS

The 94 well logs presented here are arranged alphabetically according to owners and are cross-referenced to the sheet and line number in the list of wells in the Baltimore Area.

The source of logs and their significance are discussed on page 29.

SHEET NO. 2 LINE NO. 1

American Radiator & Standard Sanitary Corporation
5315 Holabird Avenue

Well No. 1 Size: 12 in. Depth: 279 ft. Elev.: 27.5 ft.
Driller: Guar. Water Eng'g Co. (Sanford) Drilled: 1926

Log	
0-12'	Sandy loam
30	Sand and gravel
55	Sandy clay
85	Various colored sandy clays, (red, yellow, brown)
95	Clay, brown, with sand
110	Clay, red and yellow mixed with sand
136	Clay, yellow and brown with varying amounts of sand
142	Sand, brown with some clay
154	Sand, coarse, yellow
157	Sand, coarse, with gravel
160	Sand, brown
169	Sand and gravel, coarse, yellow
175	Sand, coarse, white
178	Sand and gravel, coarse
183	Sand, reddish with some clay
186	Clay, deep red
190	Clay, light red
195	Clay, gray
205	Clay, slate gray
225	Clay, yellow and brown with little sand
229	Clay, hard, reddish with sand
232	Sand, and gravel, coarse, yellow
240	Gravel, coarse with water
246	Gravel, coarse with sand
257	Sand and gravel, coarse white
267	Sand clay, fine
279	Clay, brown and yellow, hard
279	Baltimore Gneiss

SHEET NO. 2 LINE NO. 2

American Sugar Refining Company
Key Highway and Foot of Woodall Street

Well No. Size: Depth: 195 ft. Elev.:
Driller: Drilled:

Log

0-15'	Water
28	Mud
36	Fine and coarse sand
46	Hard red clay
94	Fine hard white sand
155	Coarse sand with some rocks
163	Fine quartz gravel and some rock
190	Rotten rock
195	Shattered rock
212	Bed rock (pegmatite)

SHEET NO. 4 LINE NO. 12

B & O R.R.
Coal Piers, Curtis Bay

Well No. Size: 10 in. Depth: 315 ft. Elev.: 12 ft.
Driller: Drilled: 12/23/20

Surface El 12'

SECTION

0-12'	Yellow clay
14	Gravel
15	Clay
20	Gravel
38	Coarse sand
39	Fine sand
44.5	Clay
63	Coarse sand (no water)
67	Clay
80	Coarse sand (no water)
84	Clay
123.5	Coarse sand - water
125	Boulders
129	Clay
139	Coarse sand, water?
145	Clay
148	Hard rock
185	Hard red clay
188	Coarse sand, water?
191	Red clay
197	Clay, water?
204	Clay
244	Coarse sand, water
261	Clay
271	Coarse sand, water?
276	Clay
295	Coarse sand, water?
298	Clay
310	Coarse sand, water?
315	Tough red clay

SHEET NO. 4 LINE NO. 14

B & O R.R.
Riverside Shops (1000' W. of W. Roundhouse of the R.R. yards)

Well No. 1 Size: 18 - 13 in. Depth: 180 ft. Elev.:
Driller: Layne N. Y. Co. Drilled: 1924

Elevations below surface	
0-4'	Cinders
22	Muddy sand
48	Hard red clay
57	Red clay
63	Sandy clay
74	Fine white sand
85	Hard clay
94	Muddy sand
100	Fine white sand
126	Red clay
132	Muddy sand
148	White sand
179	Coarse sand and gravel
	Hard rock

SHEET NO. 4 LINE NO. 15

B & O. R.R.
Riverside Shops (1370' W. of W. Roundhouse of the R.R. yards)

Well No. 2 Size: 13 in. Depth: 170 ft. Elev.:
Driller: Layne N. Y. Co. Drilled: 1924

Elevations below surface	
0-10'	Red clay
14	Brick
32	Tough red clay
50	Clay
60	Muddy sand
72	Packed sand
83	Muddy sand
105	Tough red clay
116	Muddy sand
125	Tough clay
132	Muddy sand
135	Sand and gravel
170	Water bearing coarse sand and gravel
	Hard rock

SHEET NO. 5 LINE NO. 5

Baltimore Refrigerating and Heating Co.
Barre & Eutaw

Well No.	20 wells	Size:	6 & 8 in.	Depth:	100 av.	Elev.:	
Drilled:	Downin					Drilled:	

Average Section

0-10'	Sand
45	Clay
55	Gravel
65	Clay
99	Rock

SHEET NO. 5 LINE NO. 7

Bay Shore Park
Pumphouse (United Railways Co.) (West Wall)

Well No.	2	Size:		Depth:	740 ft.	Elev.:	5 ft.
Driller:	Shannahan					Drilled:	1907

0-74'	River deposits
158	Red clay
178	Sand
239	White sandy clay
274	Red clay
313	Yellow and brown clay
434	Sand and gravel
490	Red clay
504	Sand
512	Sandy clay
660	Tough red clay
721	Light sandy clay
743	Sand water bearing

SHEET NO. 5 LINE NO. 6

Bay Shore Park
United E. R.R. Co.

Well No. Size: Depth: 401 ft. Elev.: 6 ft.
Driller: Shannahan Drilled: 1907

Log

0-11'	Clay brown hard
13	Sand brown soft
140	Clay blue soft
147	Gravel
196	Sand white soft
236	Sand white hard
253	Sand white soft
260	Sandstone red hard
298	Clay sticky red soft
304	Clay brown hard
319	Clay white hard
333	Sand light brown soft
371	Clay red hard
401	Sand white soft

Remarks:

The clay between 13' and 140' forms in a cake and comes out.
196-236 some clay with the sand
236-253 some water
260-298 clay very sticky
304-319 some wood in the clay

SHEET NO. 5 LINE NO. 10

Now: Baltimore Transit Co.
United R.R. & Elec. Co.
Sellers Station

Well No. Size: 6 in. Depth: 287 ft. Elev.:
Driller: Downin Drilled: Feb. 1903

Log

0-19'	Blue clay
21	Sand and gravel. Surface water
22	Blue clay
92	Red clay
105	Fine sand
115	Yellow clay to sand
131	Fine white sand
142	White clay
145	White indurated sand
149	White clay
159	White sand and clay
162	Blue clay
195	Red clay
199	White clay
201	Red sandy clay
203	Red sand
234	Gravel and sand
260	Blue clay
271	Pink clay
282	Blue clay
284	Red indurated sand
287	Red sand water

SHEET NO. 6 LINE NO. 6

Baugh Chemical Co.
Clinton and Wortons

Well No. Size: 8 in. Depth: 171 ft. Elev.:
Driller: Shannahan Drilled: 1909

Material	Color	Hardness	Depth
Filled in			0-14'
Clay	red	tough	14-35'
Clay	drab	tough	33-55
Clay	brown	tough	55-64
Clay	red	tough	64-88
Clay	red	hard	88-101
Sandy clay	pink	very hard	101-106
Sand	white	free	106-125
Streaks of clay	red	hard	125-127
Sand	white	not free	127-133
Sand	white	free	133-146
Clay	red	tough	146-149
Clay	red	sandy	149-158
Sand	white	free	157-166
Sandy-clay	red	hard	166-168
Clay	yellow	tough	168-171

SHEET NO. LINE NO.

Bennett Potteries
Canton & Central Avenue

Well No. Size: 8 in. Depth: 45-50 ft. Elev.:
Driller: Drilled:

Log	
0-20'	Black mud
30	Yellow loam
	Gravel full of water
41	Yellow clay
45	Hard "kaolin"
50	White yellow gravel full of water

SHEET NO. 7 LINE NO. 1

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. Furnace Well at Spray Pond
Driller: Shannahan　　　　Drilled: 1931-32

FORMATION:		FORMATION:	
Clay	8'-30'	Clay streaks	397'-417'
Sand	45'	Harder	453' 6"
Clay	117'	Sand	456' 6"
Hard	126'	Hard	478'
Clay, white with streaks of sand	164' 1"	Hard like s. stone	484'11"-485' 5"
Clay streaks	222' 7"	Boulder	485' 9"
Red clay	262' 8"	Soft	486' 5"
Sand	290'	Soft, hard streaks	487' 3"
Streaks of clay	291' 6"	Boulder	487' 8"
Sand	293' 8"	Softer	488' 4"
Clay, white	294' 2"	Boulder	489'
Sand	295' 6"	Soft	489' 8"
Clay	297' 6"	Hard	492'
Gravel	299' 1"	Soft	493' 3"
Clay	299'10"	Gravel	498'
Gravel	308'	Sand	506'10"
Clay	312'	Gravel	510' 2"
Sand	316'	Clay	515' 2"
Clay	379' 1"	Sandy	515' 8"
Hard place	379'10"	Sand, free	538' 4"
Clay	397'		

SHEET NO. 10 LINE NO. 3

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 27 - Coke Ovens
Driller: Shannahan　　　　Drilled: 1917

FORMATION:		FORMATION:	
Clay	15'- 30'	Sand	295'-308'
Sand	90'	Clay	434'
Clay	112'	Sand	441'
Sand	196'	Clay	443'
Sandy clay	223'	Sand water	457'
Red clay	252'	Clay	480'
Water sand	294'	Sand	482'
Clay	295'	Clay	487'
		Sand and gravel	514'

SHEET NO. 11 LINE NO. 15

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 7 - Hot Strip Well
Driller: Shannahan Drilled: 1937

FORMATION:	
Clay	0'- 40'
Sandy	50'
Sand & gravel	80'
Clay	90'
Sand	194'
Sand	202'
Clay	207'
Sand & Gravel	218' 8"
Clay	219' 2"
Sand & gravel	231' 7"
Clay	
Free sand	295'-298' 5"
Hard	
Gravel not free only in streaks	-303'
Sand free	308'
Hard	310'
Free sand	317' 4"
Crust, then free to	324'
Gravel not free	335' 6"
Clay	345' 9"
Sandy	347'
Clay	354' 4"
Hard	359'
Drifts some	362' 6"
Hard white clay	364'
Free	365'
Clay	369'
Free	371'
Free sand	374'
Hard clay	378'
Free sand	381' 6"
Hard crust	382'
Sandy clay	383'
Tough clay	383' 9"
Free sand	384' 7"
Tough clay	395' 7"
Softer clay	406'
Sand free	407' 6"

FORMATION:	
Sandy or soft clay	407' 6"-408'
Hard boulder	408' 6"
Sandy	410'
Very free sand	412'
Sand	414'
Sandy clay	416'
Clay	417' 6"
Free sand	418' 6"
Sandy	419'
Clay	420'
Hard rock	420' 3"
Very hard rock	420' 5"
Sandy free in places	423' 6"
Clay	424' 6"
Sand & clay	426' 6"
Free sand	427' 6"
Sandy clay	427'10"
Free sand	428' 8"
Sandy clay	429' 4"
Sand free & clay streaks	432' 6"
Clay	434'
Sand free	435'
Clay	435' 6"
Sandy clay	438'
Sand & gravel at top free in places	440' 6"
Sand very free some gravel	445' 6"
Hard rock	446' 4"
Clay	449' 8"
Hard rock	450' 2"
Sand clay	457'10"
Hard place	458' 3"
Clay tough	470'
Sandy & clay streaks	480'
Hard clay	503'
Softer clay	506'
Hard place	506' 6"
Very sandy	508' 6"
Hard & sandy places	520' 6"
Hard	525' 8"
Tight sand	526' 8"

SHEET NO. 11 LINE NO. 15

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 7 - Hot Strip Well (Continued)

FORMATION:		FORMATION:	
Tough yellow clay	526' 8"-532'	White clay	590' 6"-591' 6"
Sandy white "	534'	Tight gravel	593'
Tough " "	547'	Sand & hard	597' 4"
Sandy	553' 9"	Clay	597'11"
Rock	554'	Sand & hard	605' 6"
Clay red hard	570' 6"	Hard clay	610' 2"
Coarse free sand	580' 6"	Sand & hard	611' 6"
Hard red clay	583' 6"	Hard red clay	624'10"
Tight gravel	585' 6"	Sandy & stone	625' 2"
Gravel, free	589' 6"	Clay	626' 6"
Tight gravel	590' 6"	Sand free & gravel	629'

SHEET NO. 11 LINE NO. 8

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 8 - Forty-Inch Mill
Driller: Shannahan Drilled: 1929

FORMATION:		FORMATION:	
Clay 150'-	190'	Clay streaks	440' 2" 455' 7"
Sand & gravel	210'	Iron ore	456'
Sandy clay	215'	Sand streaks	461'
Red clay	268' 6"	Iron ore, hard	461' 4"
Lead color clay	285' 8"	Hard clay, streaks of sand	481' 4"
Sandy	296' 5"	Iron ore	481' 8"
Clay sandy	312'	Sand & clay	484'
Clay, harder	327' 5"	Clay, hard	516' 8"
Hard place	328'	Streaks of iron ore, hard boulder	516'10"
Red clay	367'11"	Softer	520'
Boulder	368' 1"	Sand, free in places	540'
Free sand	374' 3"	Clay, hard	544'
Sandy clay	389'	Sand, part free	557' 4"
Sand	391'	Hard, sand streaks	562' 3"
Clay	391' 6"	Hard red clay	563' 4"
Sand	394'	Sand	565' 4"
Clay	394' 6"	Edge of boulder, red Clay, iron ore	580'
Free sand	421'	Boulder	580' 2"
Sand	422' 4"		
Clay	424' 4"		
Sand streaks clay	440' 2"		

SHEET NO. 11 LINE NO. 8

Bethlehem Stee Company
Sparrows Point, Maryland

Well No. 8 - Forty-Inch Mill (Continued)

FORMATION:		FORMATION:	
Clay	580' 2"-590' 8"	Sand	628' 7"-631'
Sandy-drifts free in places with wood	616'	Clay	632'10"
Hard clay	620'	Sand	642'10"
Sand free with gravel	622'	Sand, free	655'
Sand free	627' 7"	Gravel	659'
Clay	628' 7"	White clay	660'
		Hard gravel	667' 5"

SHEET NO. 11 LINE NO. 18

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. Rail Mill Well
Driller: Shanahan Drilled: 1937-38

FORMATION:		FORMATION:	
Surface mostly filled	0'- 10'	Tough clay	424' - 424' 6"
Lead color clay	30'	Seems free	435'
Sandy	60'	Tough	438' 6"
Clay	125'	Sandy	457'
Gravel	140'	Clay	462'
Sandy	185'	Sand	463'
Clay	205'	Clay	464'
Sandy	225'	Free	466'
Hard clay	250'	Clay	476'
Rock	251'	Sandy clay	482'
Hard clay	280'	Sand, some wood, some gravel	487'
White tough clay	285' 6"	Clay	487' 6"
Free sand	293'	Free sand	488'
Free gravel & streaks of clay	301'	Hard clay	489'
Hard red clay	301' 6"	Free sand	490'
Tough blue clay	365'	Clay	497'
Rock	365' 4"	Sand, some gravel	499'
Clay	380' 6"	Clay	501'
Rock	381'	Hard clay	502' 6"
Softer clay	398'	Free sand	503'
Very sandy	415'	Hard clay	516' 6"
Clay	417'	Rock	517'
Sand	419'	Clay	523'
Free sand	424'		

SHEET NO. 11 LINE NO. 18

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. Rail Mill Well (Continued)

FORMATION:		FORMATION:	
Sandy	523'-526' 6"	Sand	578' 6"-580'
Rock	526'10"	Clay	589'
Rock	531' 6"	Sandy	590'
Sandy with hard places	538'	Clay - lead color	601'
Tough clay	540'	Sand	602'
Hard places	548'	Clay	616' 4"
Clay	550' 6"	Drifted	619'
Rock	550' 9"	Gravel	624'
Hard clay	561'	Hard	624' 6"
Hard sand	562'	Free sand & gravel	629'
Clay	564'	Tough clay	638' 3"
Sand	567'	Hard	
Rock	568' 6"	Clay in bottom was white with pink streaks	
Rock hit on edge	568' 8"	Clay	639' 6"
Hard clay	578' 6"	Hard	639'10"
		Gravel	654' 6"

SHEET NO. 13 LINE NO. 1

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. Tin Mill - No. 1
Driller: Shannahan

Drilled: 1926

FORMATION:		FORMATION:	
Slag	0'- 10'	Clay	169'-170'
Yellow clay	20'	Water sand	179'
Blue soft clay	26'	White clay	193'
Sand & Gravel	30'	Sandy, hard	202'
Soft dark clay	47'	Water sand	218'
Gravel	54'	Clay	219'
Soft dark clay	70'	Water sand	234'
Large gravel	80'	Red clay	275'
Clay	128'	Sandy	283'
Sand & gravel	142'	Hard clay	284'
Sandy clay	148'	Sand water	298'
Clay	164'	White clay	302'
Sand	166'	Water sand	318'
Clay	167'	Crust	
Sand	169'	Sand and gravel	326'

SHEET NO. 13 LINE NO. 1

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. Tin Mill - No. 1 (Continued)

FORMATION:		FORMATION:	
White clay	326'-371' 6"	Hard rock	502' 2"-502' 7"
Clay	373' 6"	Sandy clay	543'
Rock	374'	Hard clay	559'
Sandy with wood	401' 3"	Red clay hard	559' 4"
Hard rock	401'10"	Sand free	561'
Sandy	406'	Sandy clay	563'
Hard rock	406' 3"	Sand & gravel	567'
Sand with clay	421'	Hard	580' 8"
Rock	421' 3"	Sand free red	584'11"
Sandy	443' 9"	Hard rock	585' 2"
Rock	444'	Sandy	596'
Hard place, several rocks	462' 5"	Red clay hard	597'
Hard rock	462' 8"	Gray clay	608'
Sandy clay	472' 5"	Sandy	619'
Rock	472' 8"	Sand and wood	629'
Clay	473' 8"	Harder	635' 7"
Hard rock	474'	Sand free	645'
Clay hard with boulders	496' 9"	Hard gravel	654'
Hard clay	502' 2"	Free not so much gravel	663'
		Tight gravel, mostly sand	667' 3"
		Hard gravel	668'11"

SHEET NO. 14 LINE NO. 9

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 21 - Old Town Water Supply -- is now: Furnace - Well No. 6
Driller: Shannahan Drilled: 1913

FORMATION:		FORMATION:	
Yellow clay	0' -20'	Red clay	220' - 225'
Blue clay	30'	Sand and gravel	234'
Green sand	45'	Red clay	250'
Blue clay	100'	Coarse sand & gravel	281'
White sand & gravel	128'	White sandy clay	300'
Red & white clay	148'	Red clay	303'
White sandy clay	165'	Coarse white sand	313'
White sand	204'	Red clay	316'
Coarse white sand	220'	Red clay, sandy	319'

SHEET NO. 14 LINE NO. 9

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. 21 - Old Town Water Supply -- is now: Furnace - Well No. 6
(Continued)

FORMATION:	
Brown clay	319'-321'
Pink tough clay	324'
Pink & white tough clay	365'
Brown clay, tough	394'
White sand	399'
Pink clay, hard	399' 6"
White sand	400'
Red clay	407'
Brown clay, sandy	412'
Red clay, tough	414'
Red clay, sandy	431'
White sand free	434'
Red clay, sandy	450'
Red clay, very hard	460'
Streak of sand	461'
Red clay, very hard	464'
Yellow clay, hard	469'
Red clay, very hard	470'

FORMATION:	
Red clay, tough	470'-477'
Pink clay, tough	482'
White sand	483'
Red clay	490'
Red clay, very hard	493'
Red clay, sandy	496'
Rock	496' 4"
Pink sandy clay	499'
Pink clay	500'
White clay	503'
White sand, fine	510'
White coarse sand	515'
Red clay	518'
White clay	528'
White sand	531'
White sandy clay	535'
Pink clay, hard	536'
Free, coarse white sand	576'

SHEET NO. 14 LINE NO. 21

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. New Water Works - No. 6
Driller: Shannahan Drilled: 1919

FORMATION:	
Yellow clay	0'- 6'
Sandy	10'
Dark clay	123'
Sand & gravel	134'
Sand, white	158'
Sand, free in places	193'
Clay, hard	196'
Sandy	199' 6"
Sand, free	220'
Clay	220' 6"

FORMATION:	
Sand, free	220' 6"-225'
Clay	227'
Clay, harder	232'
Sand	243'
Clay, hard	248'
Sand, free	255'
Clay	256'
Sand, not free	270'
Clay, hard	272'

SHEET NO. 14 LINE NO. 21

Bethlehem Steel Company
Sparrows Point, Maryland

Well No. New Water Works - No. 6 (Continued)

FORMATION:		FORMATION:	
Sand, free in places	272'-300'	Hard	594'9"-595' 9"
Sandy	338' 7"	Sandy	603'11"
Clay	341'	Sandy free	609'11"
Sand, gravel	343'	Sand & little water	615'11"
Clay, red, hard	489'	Clay	617' 7"
Clay, red, softer	499'	Sand, free	621' 7"
Clay, red, hard	510'	Clay, hard	627'10"
Sandy clay	512'	Clay, harder	659'
Clay, hard	512' 6"	Clay, softer	680'
Clay, harder	559'	Sand, free	692' 2"
Clay, red	587'	Hard place	696' 2"
Sandy clay with streaks of free sand & wood	594' 9"	Gravel	706'

SHEET NO. 16 LINE NO. 9

Boyle, J. & Company
Thames & Wolfe Streets

Well No. Size: 3 in. Depth: 142 ft. Elev.:
Driller: Drilled: 1884

Log

0 - 20'	Filled
30	Yellow pine pile
40	Yellow clay
45	Coarse sand and gray gravel (brackish water)
70	Red clay
75	Gravel (water)
100	Blue clay
142	Micaceous clay and sand
	Hard rock

SHEET NO. 16 LINE NO. 14

August Bridenstein
Lauraville

Well No. Size: 3 in. Depth: 38 ft. Elev.: 250 ft.
Driller: Baltimore Artesian Well Co. Drilled: 1904

Log

0 - 20'	Red clay
35	Quicksand
38	Sand, gravel and water

SHEET NO. 16 LINE NO. 17

Buck Glass Company
Fort & Lawrence Streets

Well No.	Size: 8 in.	Depth: 119 ft.	Elev.:
Driller: C. Hoshall			Drilled: 1923

Log

0 - 55'	Red clay
60	Yellow sand with a little water
70	Red clay
90	White clay
96	White clay with sand
99	White sand with water
103	Red clay with a little iron ore
119	White sand and white clay
	Water bearing gravel

SHEET NO. 17 LINE NO. 3

Camp Holabird
Holabird Avenue

Well No. 270	Size: 12 in.	Depth: 300 ft.	Elev.:
Driller:			Drilled: 1936

Log

0 - 37'	Surface soil, sand, clay
38'	Hard rock
242'	Non water bearing, varicolored clays
258'	Fine sand, clean but little showing of water
260'	Hard trap rock
291'	Good clean but fine water bearing sand

Note: 17 1/2" drilled hole with 12" casing

SHEET NO. 17 LINE NO. 10

Canton Distilleries Co.
Clinton and 4th Avenue

Well No.	Size: 8 in.	Depth:	Elev.:
Driller:			Drilled:

Log

80 - 85'	Water bearing
145	Yellow clay
235	Sand and gravel grading to rock

SHEET NO. 17 LINE NO. 11

Canton Ice Co.
1st Street & Canton Avenue

Well No. Size: 6 in. Depth: 400 ft. Elev.:
Driller: Rust Drilled: 1910

Log

160 - 170'	Sand (small stream)
240	Yellow clay
260	Sand and gravel (water bearing)
320	Yellow clay (water bearing)
	Loose shell like rocks - water

SHEET NO. 17 LINE NO. 14

Canton Power House Co.
10th & 5th Avenues

Well No. Size: 8 in. Depth: 198 ft. Elev.:
Driller: Drilled:

Log

0 - 18'	Sand
19	Gravel
45	Sand
47	Clay
67	Sand with little clay
69	Coarse sand & gravel, water
	thin band of compact sand underlain with thin bed of clay
170	Fine sand with occasional very thin gravel bed
	thin clay bed, 2' of gravel with a little water 3' of very hard clay
198	Clean coarse gravel yielding 100 g.p.m.

SHEET NO. 18 LINE NO. 1

Chemical and Pigment Co.
6401 St. Helena Avenue

Well No. 0 Size: Depth: 338 ft. Elev.: 15 ft.
Driller: Shannahan Drilled:

Log
River mud to 50'

50 - 70'	Sand
108	Red clay
112	Sandy
145	Clay hard sand with clay
146	Boulder
157 - 8"	158-8". Boulder
168	Sand
210	Hard
210-230	Soft clay with little sand
230	Hard boulder 2" thick, broke it and drove it down, still in clay at 236
236-240	Sand and clay
269- 6"	Sand
274- 9"	Clay
282- 9"	Free with gravel
290	Hard place - like clay

Said water started 320 to 338

SHEET NO. 19 LINE NO. 1

Chesapeake Paper Board Co.
Key Highway and B & O R.R.

Well no. Size: 6 in. Depth: 156 ft. Elev.:
Driller: Drilled: July 1934

Log

20	Cinder fill
27	Fine gray sand
64	Hard drilling red clay
67	Hard sandstone
69	Fine clay
137	Hard drilling tough red clay
137 - 156	Sand, gravel, boulders, streaks of clay
164	Blue clay

SHEET NO. 19 LINE NO. 2

Chesterwood Free EXC. Soc.
Bear Creek, Baltimore County, Md.

Well No. Size: 4 1/2 in. Depth: 172 ft. Elev.:
Driller: Shannahan Drilled: 1903

Log

0 -	110'	Sand with iron crusts
	145	Tough red clay (like clay at Powerhouse at 226')
	155	White sandy clay
	172	Coarse white sand

W = 0 (Sea level)
B = -172'

SHEET NO. 19 LINE NO. 11

Consolidated Gas & Electric Light & Power Co.
Sollers Station, Baltimore County, Md.

Well No. Size: 8 in. Depth: 226 ft. Elev.:
Driller: Shannahan Drilled: July 1903

Log

0 -	20'	Yellow clay formed surface spring
	50	Boulders
	84	Boulders
	120	Sand soil
	154	-
	157	Coarse red sand (water pump 20 gal.)
	200	Tough red clay
	226	Coarse sand nearly white. Water bearing. Pumps 110 gpm

W = 0 (Sea level)
A = -226
A = -157
B = -226

SHEET NO. 20 LINE NO. 5 & 6

Continental Oil Co.
Baltimore, Maryland

Well No. 4 and 5
Driller: Shannahan

Drilled: 1936

FORMATION: Continental Oil Company's No. 4 Well

Gravel	62' 4" -	
Streaks of clay	96'	
Sandy clay	97' -	97'
Red & blue clay		141'10"
Boulder		150' 2"
Hard place		165' 2"
Sandy & wood		174'
Hard		174' 7"
Boulder		177'10 3/4"
Soft		202'
Boulder		202' 3"
Clay		209'
Boulder		209' 3"
Sandy		227'10"
Think this carried good flow of water		
Hard clay		251' 3"
Hard place		251' 6"
Sand & gravel		272'
Clay & iron ore		273' 6"
Clay - hard		306'
Soft		314'
Gravel		343' 9"
Rock		344' 7"

GRAVEL CONDUCTOR: East Well. Continental Company's No. 5 Well

6" pipe, no shoe	201'11"
8" pipe	93 5
Coupling shoes on bottom	

West Well

6" pipe, no shoe	202'
8" pipe	93 9
Coupling shoes on bottom	

SHEET NO. 20 LINE NO. 5 & 6

Continental Oil Company
Baltimore, Maryland

Continental Oil Company's Well No. 5 (Continued)

FORMATION of No. 5 Well: These measurements from top of 16" pipe. Add 2' 8" to top of foundation.

Clay	Surface	45'
Gravel	45'	48'
Sandy clay	48	69
Sand, free	69	84
Tough clay	84	142
Sandy	142	147
Hard granite rock (hardness of 7)	147 5	148 9
Clay	148 9	
Tough clay	190	202
Sand & gravel	202	216
Tough clay from	216	250 9
Hard	250 9	251 9
Sand & gravel	251 9	255 9
Sand on to	255 9	259 9
(This had some clay streaks)		
Clay streaks some sand & gravel	259 9	269
Not much good below 259'		
Sandy	290	297 6
Hard at		297 6
Sand at		302 6
(Think sand started 2' higher)		
Sandy	304	315
Hard place	315	315 6
Sand & gravel free in places	315 6	328
Sandy clay	328	334
Sandy, almost free	334	337
Clay	337	344
Rock	344	

CC to L.O.S.
CC to N.M.S.

SHEET NO. 21 LINE NO. 9

Crown Cork & Seal Co.
Eastern Avenue and Kresson

Well No. 3 Size: Depth: 234 ft. Elev.:
Driller: Harris-Harmon Well Co. Drilled: 1941

Log

0 - 20'	Surface fill & gravel
40	Sand & gravel
69	Red clay
81	Boulders, gravel & sand
97	Tough clay
105	Boulders in clay
130	Clay
168	Sandy clay & gravel
180	Fine sand streaked with clay
190	Sandy clay and gravel
215	Medium sand, water bearing, with balls of clay
219	Heavy gravel embedded in very tough clay & mica
227	Dark blue clay & weathered mica rocks
234	Mica rock

Water sand 190 to 219 ft.

SHEET NO. 21 LINE NO. 7

Crown Cork & Seal Co.
Highlandtown Plant - Eastern Avenue & Kresson

Well No. 1 Size: 12 in. Depth: 233 ft. Elev.:
Driller: Harris-Harmon Well Co. Drilled: 10/21/39

Log

0 - 10'	Fill
40	Sand & boulders
178	Clay
196	Water bearing sand & gravel
200	Mica
210	Water bearing sand & gravel
212	Mica
220	Water bearing sand & gravel
231	Mica
233	Bed rock

SHEET NO. 23 LINE NO. 11

Davison Chemical Co.
Curtis Creek

Well No. 2 Size: 6 in. Depth: 460 ft. Elev.: 10 ft.
Driller: Shannahan Drilled:

Log

Material	Color	Hardness	Depth
Clay	Yellow	Soft	0- 5
Clay	Dark drab	Soft	5- 25
Clay	Dark drab	Hard	25- 38
Sand & gravel			38- 49
Clay	White	Soft	49- 64
Sand	Yellow		64- 66
Clay	White	Soft	66- 71
Sand	White	Free	71- 75
Clay	Yellow	Soft	75- 76
Sandy-clay-	White	Soft	76- 95
Coarse sand	White	Soft	95-106
Clay	White	Soft	106-110
Clay	Red	Hard	110-111
Clay	Pink-white	Hard	111-121
Clay	Brown	Soft	121-125
Clay	Pearl gray	Soft	125-132
Clay	Red	Soft	132-175
Sandy-clay	Drab	Soft	175-180
Clay	Red	Soft	180-195
Sandy-clay	Drab	Soft	195-218
Clay	Dull red	Hard	218-223
Clay	Bright red	Hard	223-225
Sand	Yellow	Free	225-241
Clay	Red	Hard	241-244
Sand & rock	Red	Hard	244-257
Sand	White & yellow	Free	257-274
Clay	Red	Hard	274-281
Sand & gravel	White	Free	281-335
Iron ore	Red	Hard	335-337
Clay	Red	Hard	337-338
Clay	Drab	Soft	338-358
Iron ore	Red	Hard	358-362
Sand	White	Free	362-365
Clay	White	Soft	365-368
Sandy-clay	White	Soft	368-370
Clay	Pink	Hard	370-374
Sand	White	Free	374-385
Clay	White	Soft	385-391
Clay	Yellow	Hard	391-399
Clay	Pink	Hard	399-401

SHEET NO. 23 LINE NO. 11

Davison Chemical Co. Well No. 2 (Continued)

Material	Color	Hardness	Depth
Iron ore	Pink	Hard	401-402
Clay	Pink	Hard	402-405
Clay	Drab	Soft	405-429
Clay	Drab	Hard	429-435
Sandy-gravel	White	Water bearing	435-460

SHEET NO. 23 LINE NO. 15

Davison Chemical Co.
Curtis Bay

Well No. 6 Size: 6 in. Depth: 316 ft. Elev.:
Driller: Shannahan Drilled:

Log

0 - 10'	Shells, etc.
12	Shore sand
20	Gray clay
44	Dark clay
48	Yellow clay
60	Sand & gravel
61	White clay
70	Sand & gravel
80	Red clay
126	Sandy red and white clay
195	Red clay
218	Gray clay
225	Red clay
241	Yellow sand
250	Sand
260	Sand
280	White clay
290	White sandy clay
307	White sand
316	Red clay

SHEET NO. 23 LINE NO. 16

Davison Chemical Co.
Curtis Bay Plant

Well No. 7 Size: Depth: 339 ft. Elev.: 20 ft.
Driller: Shannahan Drilled: 1928

Log

0 - 13'	Sandy
14' 6"	Clay
16' 6"	Sandy
31	Clay
35	Sandy clay
75' 6"	Hard clay with gravel
99' 6"	Sand & clay
137' 6"	Clay
166	Sandy clay
169	Red clay
173	Sand & gravel
195	Streaks of iron ore & clay
200	Soft clay
251' 3"	Clay & sand streaks
251' 9"	Iron ore
267	Sand & clay
280	Sand
288	Sand
290	Free sand
294	Clay
319	Free sand
322	Clay
339	Free sand

Screen 323' 10" to 336' 3"

SHEET NO. 23 LINE NO. 17

Davison Chemical Co.
Curtis Bay Plant

Well No. 8 Size: 16 in. Depth: 335 ft. Elev.: 20 ft.
Driller: Harris-Harmon Well Co. Mineola, N. Y. Drilled: 1939

Log

0 -	10'	Sandy
	20	Yellow sand
	65	Gravel & gray clay
	73	Gravel in clay
	95	Coarse sand, fine gravel with clay
	137	Coarse gravel
	167	Clay
	200	Iron ore
	205	Red sandy clay
	210	Brown sandy clay
	215	Red & brown sandy clay
	235	Red sandy clay
	240	Red clay
	250	Gray sandy clay
	255	Blue clay
	260	Gray, red, yellow sandy clay
	265	Pink sand
	270	Fine yellow sand
	275	Brown sand
	280	Brown sandy clay
	285	Brown sand & clay
	290	Yellow brown sand & clay
	300	Yellow sand
	305	Brown yellow sand
	310	Brown sand

Wash samples to 200', Driven samples 200' to 310'
Driller reported water bearing sand to 335' and red clay
335 to 340'. 8" screen set 295 to 335'. H. C. Barksdale

SHEET NO.24 LINE NO. 2

Eastern Rolling Mills
Rolling Mill Road

Well No. 1 Size: Depth: 182 ft. Elev.:
Driller: Shannahan Drilled:

Log

0 -	37'	Hard clay
	38	Sand
	45	Yellow sandy clay
	59	Sand
	94	Red and yellow clay
	94' 6"	Iron ore
	97	Sandy
	104	Hard sand, fine
	126	Clay
	137	Hard sand, fine, wood
	140	Sandy
	147	White sand
	161' 8"	Sand
	162	Clay
	182	Sand & gravel
	182	Red rock

SHEET NO.24 LINE NO. 12

Eastern Rolling Mill Co.
Rolling Mill Road

Well No. 11 Size: Depth: Elev.:
Driller: Ohio Drilling Co. Drilled: 1928

Log

0 -	15'	Sand
	40	Clay
	45	Sand
	120	Clay
	135	Sand
	144	Clay
	157	Sand
	158	Clay
	162	Sand
	169	Clay
	175	Sand

SHEET NO. 26 LINE NO. 2

Emerson Hotel
Calvert & Bank Lane

Well No. Size: 10 in. Depth: 90 ft. Elev.:
Driller: T. B. Harper, Jenkinstown, Pa. Drilled: 1911

Log

0 - 31'	Cellar
57	Sand & gravel, water bearing at 55'
76	Mixed clay
90	Rock

SHEET NO. 28 LINE NO. 2

Fort Carroll

Well No. Size: 6 in. Depth: 168 ft. Elev.:
Driller Drilled: 1900

Log

0 - 10'	White sand fill
56	Yellow sand mixed with oyster shells
97	Yellow clay
123	Gray white sand & gravel, little water
150	White fire clay
156	Coarse white sand and gravel. Water.

W = 10'
A = - 158
A = - 113
B = - 158

SHEET NO. 28 LINE NO. 10

Frankfort Distillery
200 N. Kresson St. between Fayette & Fairmont

Well No. 1 Size: Depth: 238 ft. Elev.:
Driller: Probably Washington Well & Pump Drilled: 1933

Log

0 - 5'	Fill
15	Sandy clay
25	Sand
30	Sand & gravel
33	Mixed sand & gravel
38	White clay & silica
41	White and red sand
44	Red clay, sand & gravel
49	Red, yellow-white clay, sand & gravel

SHEET NO. 28 LINE NO. 10

Frankfort Distillery

Well No. 1 (Continued)

Log

54'	White & yellow clay
56	White clay & sillica
59	White yellow red clay. Coarse sand
69	Red brick clay
71	Red clay, streaks of blue
73	Sand carrying water
96	Red clay, streaks of white
118	Clay & sand
123	Sand & clay
130	Sand & gravel
135	Red-white-yellow clay. Sand & gravel
150	Sand & gravel
155	Sand with mica & gravel
160	Sand with mica & water bearing gravel
175	Alum & sand
182	Coarse sand
189	Green shale & sand muscovite
204	Green shale sand & graphite
208	Graphite
232	Green shale sand & graphite

SHEET NO. 29 LINE NO. 9

Gibson Island Corp.
Gibson Island, Md.

Well No. 1 and 2 Size: Depth: 319 & 322 ft. Elev.: 25 ft.
Driller: Shannahan Drilled: Mar. 1923 and 1929

Log

0 - 15'	Light red clay
45	Sandy clay
53	Hard red clay
80	Sandy white clay
85	Red clay
90	White sand
120	White sandy clay
152	Red clay
159	Hard sand
166	Sandy clay with wood
170	Red clay
181	Hard sand
197	Sandy clay with gravel

SHEET NO. 29 LINE NO. 9

Gibson Island Corp.

Well No. 1 and 2 (Continued)

Log

220'	White clay
231	Yellow clay
260	Sandy clay white
275	Red clay
285	Fine sand
286	Red clay
294	White clay
322	White sand

SHEET NO. 31 LINE NO. 18

Ice Works
Wolfe and Fell Streets

Well No. Size: 8 in. Depth: 317 ft. Elev.:
Driller: Drilled:

Log

0 - 25'	Filling
30	Black mud
42	Pinkish clay
47	Sand & gravel: brackish water
95	Variegated clay
97	Sand & gravel: good water
155	Variegated clay: sand streaks
157	Gravel & sand: much good water
	Hard black rock to 317'

SHEET NO. 33 LINE NO. 9

Lauer & Suter
Block & Caroline

Well No. Size: 3 in. Depth: 99 ft. Elev.:
Driller: Baltimore Artesian Well Co. Drilled: 1904

Log

0 - 10'	Surface soil
35	Red clay
45	Fine sand
48	Gravel (water)

SHEET NO. 35 LINE NO. 3

Maryland Distillery Co.
Halethorpe, Maryland

Well No. 2 Size: 10 in. Depth: 103 ft. Elev.:
Driller: Washington Well & Pump Co. Drilled:

Log

0 -	11'	Yellow soil & clay
	14	Yellow sandy clay
	25	Yellow sand
	43	Red gravel & clay
	50	Yellow water sand
	73	Blue clay
	79	Blue clay & gravel
	86	Gravel - no water
	91	Gravel & white clay
	103	Water sand & gravel

SHEET NO. 35 LINE NO. 4

Maryland Distillery Co.
Halethorpe, Maryland

Well No. 3 Size: 10 in. Depth: 107 ft. Elev.:
Driller: Washington Well & Pump Co. Drilled:

Log

0 -	14'	Yellow soil & clay
	28	Red clay
	45	Red clay & gravel
	49	Yellow sand
	53	Red clay
	60	Yellow water sand
	86	Blue clay
	95	Blue clay & gravel
	107	White water sand & gravel

SHEET NO. 35 LINE NO. 6

Maryland Distillery Co.
Halethorpe, Md.

Well No.: 4 Size: 10 in. Depth: 103 ft. Elev.:
Driller: Washington Well & Pump Co. Drilled:

Log

0 - 6'	Yellow sandy soil
18	Red clay
31	Red clay & gravel
58	Red clay
84	Blue clay
91	Blue clay & gravel
103	White gravel & sand

SHEET NO. 35 LINE NO. 5

Maryland Distillery Co. Inc.
Halethorpe, Md.

Well No. 5 Size: 10 in. Depth: 125 ft. Elev.:
Driller: Washington Well & Pump Co. Drilled:

Log

0 - 9'	Yellow top soil
22	Red clay
39	Yellow clay
46	Yellow clay & gravel
53	Yellow sand no water
81	Blue clay
97	Blue and white clay and gravel
109	White gravel and sand
119	Greenish blue clay
125	Rotten rock
At 125	Solid rock

SHEET NO. 35 LINE NO. 10

Maryland Drydock Co.
Fairfield, Md.

Well No. 2 Size: Depth: 262 ft. Elev.: 10 ft.
Driller: Drilled: 1926

Log

0 - 8'	Fill
40	Sand & gravel
45	Dark clay
90	Red clay
90' 9"	Rock
112	Fine sand with clay
138	Brownish clay, fine sand mixed to thin rock
176	Fine sandy clay
182	Water bearing sand, coarser clay
190	Water bearing sand, more clay
210	Water bearing sand, hard picketed with scale of sandstone
230	Fine sand with thin layers of blue marl
230' 4"	Hard layer of sandstone, water bearing
252	Sand (coarse) layers of sandstone about every 3'
262	Sand and clay, coarse gravel

SHEET NO. 35 LINE NO. 17

R. B. Mason
Lauraville

Well No. Size: 3 in. Depth: 108 ft. Elev.: 320 ft.
Driller: Baltimore Artesian Well Co. Drilled: 1895

Log

0 - 3'	Surface
48	Red clay
50	Red ochre
60	Cemented gravel
100	Blue "minebank" clay with iron ore
108	Sand and fine gravel - water excellent
112	Micaceous sand & clay - no water
112	Rock

SHEET NO. 36 LINE NO. 16

Monumental Brewing Co.
Lombard & 7th Streets

Well No.: Size: 8 in. Depth: 535 ft. Elev.:
Driller: Drilled: 1910

Log

0 - 80'	Red clay
110	Fine yellow sand (water bearing)
160	Red clay, mostly
190	Sand & gravel (water)
210	Fine white sand
310	Hard pan. Loose conglomerate of small gravel and coarse sand; variegated clay - blue, yellow, white and slightly greenish
535	Gneiss rock, alternatingly hard and soft

SHEET NO. 37 LINE NO. 11

National Enamel Co.
Light & Wells Streets

Well No. Size: 6 in. Depth: 167 ft. Elev.:
Driller: Downin Drilled: 1902

Log

0 - 50'	Fill
69	River bed gravel
142	Variegated clays & marls
167	Soft crumbling sandrock bearing water

SHEET NO. 37 LINE NO. 15

Northern Central R.R.
10th Street & 5th Avenue

Well No. Size: 8 in. Depth: 197 ft. Elev.:
Driller: Drilled:
Depth of water bearing formations: 190 - 197 in coarse gravel.

Log

0 - 7'	Sand & gravel
29	White clay
38	Gravel & yellow clay
56	Red clay
74	Sand & white clay
80	Yellow clay
83	Light yellow clay
89	White clay
99	Yellow clay
118	White sand
123	White clay
128	Coarse sand
129	White clay
137	Yellow clay
144	White clay, sand & gravel
158	Light sand
159	Light clay
179	Red sand
180	Coarse light red sand
183	Small gravel
187	Gravel, sand & clay
190	Clay
197	Coarse gravel, water

SHEET NO. 39 LINE NO. 4

Pan American Refining Co.
Southport Avenue, E. Brooklyn, Md.

Well No. 4 Size: Depth: 396 ft. Elev.:
Driller: Shannahan Drilled: May 1939

Log

0 - 15'	Blue clay
22	Sand
33	Gravel
43	Clay & gravel
85	Sand & gravel
90	Clay
98	Sand & gravel
102	Clay
151	Sandy clay
188	Red clay
215	Sandy clay
216	Boulder
243' 7"	Clay
243' 11"	Boulder
280	Clay
280' 8"	Boulder
282' 6"	Clay
289' 6"	Sandy clay
290	Clay hard
318	Sandy
321	Clay
321' 2"	Boulder
354	Clay
376	Sandy clay
393	Sand gravel
395' 4"	Bed rock

SHEET NO. 39 LINE NO. 5

C. H. Pearson & Co.
Packers

Well No.:	Size:	Depth: 102 ft.	Elev.:
Driller:			Drilled:

Log

0 - 8'	Shells
15	Mud
22	Mud with shells & gravel
30	Red clay
45	White clay
60	Sandy white clay
65	Sand - rock
80	White impervious clay
102	Water-bearing white sand

SHEET NO. 39 LINE NO. 7

Pennsylvania Water & Power Co.
Philadelphia Road & 8th Street

Well No.:	Size: 6 in.	Depth: 395 ft.	Elev.:
Driller: Hoshall			Drilled: 1910

Log

0 - 125'	Mostly sand with some clay
375	Mica rock
395	White granite

SHEET No. 43 LINE NO. 13

Schluderberg-Kurdle Co.
Baltimore & Eaton

Well No. 2 Size: Depth: 195 ft. Elev.:
Driller: Guarantee Water Eng'g Corp. Drilled: 1928

Log

0 - 15'	Cinders and fill
20	Sandy clay
40	Tough red clay
49	Sand & clay
53	Boulders
60	Sandy clay
85	Yellow sand
94	Fine yellow sand
136	Tough yellow clay
148	Coarse gravel & sharp fine sand
154	Sand
161	Tough clay
195	Coarse sand to gravel at bottom

SHEET NO. 43 LINE NO. 14

Schluderburg-Kurdle
Baltimore and Eaton

Well No. 1 Size: 18 in. Depth: 195 ft. Elev.:
Driller: Guarantee Water Supply (out of business) Drilled: 1928

Log

0 - 15'	Cinders and fill
34	Red clay
39	Pack sand
59	Yellow clay
69	Hard pack sand
77	Hard pack sand
81	Shale
109	Red gumbo
117	Fine sand
123	Gumbo
129	Sand
149	Coarse sand
152	Gravel
195	Coarse gravel

SHEET NO. 43 LINE NO. 16

Schluderburg-Kurdle
Baltimore & Eaton

Well No.: 3 Size: 8 in. Depth: 272 ft. Elev.:
Driller: Layne Atlantic Co. Drilled: 1941

Log

0 - 12'	Brick & cindor fill
144	Hard red clay
161	White sand
168	Hard blue clay
189	Sand & gravel
223	Vari-colored clay, small boulders
245	Sand & gravel
262	Soft blue clay
267	Dark gray sand, possibly weathered granite
272	Granite

SHEET NO. 43 LINE NO. 18

Schluderburg-Kurdle
Baltimore & Eaton

Well No.: 4 Size: 8 in. Depth: Elev.:
Driller: Layne Atlantic Co. Drilled: 1943

Log

0 - 15'	Clay, light gray to maroon mottled
35	Sand, buff, moderately coarse
110	Clay
137	Clayey sand
142	Gravel and some clay pellets and balls
147	Sand & gravel with clay balls
155	Quartz gravel and sand with some clay balls
169	Gravel, sand clayey
179	Sand & gravel with clay balls
195	Sand & gravel, drilled 5' every 8 hours

SHEET NO. 44 LINE NO. 3

Sharp & Dohme
Pratt & Howard

Well No. Size: 6 in. Depth: 85 ft. Elev.:
Driller: Downin Drilled:

Log

0 -	10'	Yellow sand
	48	Gravel & sand
	68	Yellow clay
	85	Rock

SHEET NO. 44 LINE NO. 5

Sharp & Dohme
Pratt & Howard

Well No.: Size: 6 in. Depth: 77 ft. Elev.:
Driller: Downin Drilled:

Log

0 -	20'	White clay
	47	Sand & gravel
	65	Yellow clay
	73	"iron ore"
	77	Yellow clay
		Rock

SHEET NO. 44 LINE NO. 4

Sharp & Dohme
Pratt & Franklin

Well No.: Size: 6 in. Depth: 94 ft. Elev.:
Driller: Downin Drilled:

Log

0 -	22'	Top soil
	24	Blue sand
	31	Sandy, yellow clay
	88	Clean yellow sand
		Rock

SHEET NO. 45 LINE NO. 3

Southern Products Co.
Bodkin Creek (Sanitary Reduction Co.'s Garbage Plant)

Well No. 1 Size: 8 in. Depth: 431 ft. Elev.:
Driller: Shannahan Drilled: 1908

Log

0 - 20'	Sand, white hard
22' 6"	Clay, white hard
24' 6"	Sand, yellow coarse
30	Sand, white free
54	Sand, yellow not free
72	Sandy clay white hard
80	Sand, yellow and white free
95	Sandy clay white hard
100	Clay, dark gray hard
105	Sandy clay white hard
125	Sandy clay red hard
141	Sand, red free
143	Clay, white hard
150	Sand, red not free
151	Clay, red hard
154	Clay, white hard
160	Sand, yellow not free
235	Clay, red tough
266	Clay, brown soft
273	Sandy clay red soft
275	Sandy clay red soft
277	Sand, red free
279	Clay, red soft
288	Clay, brown soft
295	Clay, red tough
390	Sand, white hard
431	Sand, white free

SHEET NO. 45 LINE NO. 5

STAFFORD HOTEL
Madison & Charles

Well No.: Size: 8 in. Depth: 315 ft. Elev.:
Driller: Drilled: 1905

Log

0 - 54'	Light sand #1
65	Yellow clay becoming lighter
80	Soft gray rock #3
90	Rock becoming harder
115	Rock 5
130	Darker 6
140	Harder 7
150	" 8
160	" 9
170	" 10
180	" 11
190	" 12
198	" 13
210	Somewhat softer 14
220	Hard 15
223	Hard 16
230	Lighter in color 17
240	" " " 18
250	" 19
255	" 20
265	Darker 21
280	" 22
300	" 23
315	" 24

* Water 15 gpm just above harder rock at 90'

SHEET NO. 46 LINE NO. 8

Standard Oil Co.
5th Street & P. B. & W. R. R.

Well No.	Size: 6 in.	Depth: 200 ft.	Elev.: 40 ft.
Driller: Shannahan			Drilled: 1907

Log

0 - 6'	Yellow clay
76	White sand
82	Red clay
126	Reddish sand
157	Variegated sandy clay
166	White clay
187	Sand & gravel
200	Gray micaceous material carrying some garnetiferous material

SHEET NO. 46 LINE NO. 11

Standard Oil Co.
Boston Street (250' So. of) (W. side of Newkirk)

Well No. 1	Size: 12 in.	Depth: 224 ft.	Elev.:
Driller: Layne N.Y. Co,			Drilled: Feb. 1926

Log

0 - 10'	Sand
15	White clay
35	Sand
90	Red clay
92	Sand
108	Blue clay
113	Fine sand
216	Coarse sand & gravel
224	Boulders

SHEET NO.46 LINE NO. 12

Standard Oil Co.
Boston St. (750' S. of Boston St., W. side of Newkirk)

Well No. 2 Size: 18 in. Depth: 229 ft. Elev.:
Driller: Layne N. Y. Co. Drilled: April 1929

Log

0 - 35'	Sandy soil & clay
43	Sandy clay
68	Sand
69	Boulders
109	Sandy clay
116	Sand
117	Boulders
160	Sand
162	Clay
166	Sand
191	Clay
206	Sand
229	Sand

SHEET NO. 46 LINE NO. 13

Standard Oil Co.
Boston St. (1250' S. of Boston St., W. side of Newkirk)

Well No. 3 Size: 18 in. Depth: 224 ft. Elev.:
Driller: Layne N. Y. Co. Drilled: 6-1929

Log

0 - 83'	Clay & fill
93	Sandy clay
133	Sand
145	Clay
156	Sand
159	Clay
174	Sand
184	Clay
224	Sand

SHEET NO. 46 LINE NO. 14

Standard Oil Co.
Canton Refinery

Well No.	Size: 18 in.	Depth: 224 ft.	Elev.:
Driller: Layne Atlantic Co.			Drilled: 1928

Log

Alternating clay strata to 117'

117 - 160	Sand
191	Clay
206	Sand
224	Sandy clay

SHEET NO. 46 LINE NO. 15

Standard Oil Co.
Canton

Well No. 4	Size:	Depth: 223 ft.	Elev.:
Driller:			Drilled: 7-1936

Log

0 - 8'	Red clay
21	Brown sand fine
46	Soft sandy clay
56	Hard red clay
57	Sandstone
66	Soft clay
68	Gray sand
98	Soft sandy clay
105	Hard red clay, hard drilling
106.5	Brown sand
109	Blue clay hard
111	Coarse gray sand
121	Soft sandy clay
126	Hard red clay, very hard
128	Coarse brown sand
157	Hard red clay, very hard
160	Coarse gray sand
169	Hard red clay, very hard
176	Coarse gray sand very sharp
184	Hard red clay
185	Sandstone
202	Coarse gray sand & gravel
216	Hard blue clay
223	Honeycombed rock
223	Ledge

SHEET NO. 46 LINE NO. 16

Standard Wholesale Phosphate Co.
Curtis Avenue & Aspen St.

Well No. 3 Size: 8 in. Depth: 344 ft. Elev.:
Driller: Shannahan Drilled: Feb. 1929

Log # 3, Air lift, February 1929
Same as 1 to 63

63 - 71'	Clay
79	Sand
85	Clay
95' 6"	Sandy
170-4	Clay
170-10	Boulder
178	Clay
178-6	Boulder
190	Cley
191	Sand
197	Clay, sand streaks
203	Clay boulder at 200' 4"
204	
206	
210-6	Clay hard
211-6	Soft rock
214	Clay hard
214-215	Soft
242	Clay, sand streaks
247	Clay
249	Soft
268	Sandy clay
281	Free sand
290	Sand & gravel
296	Sand free
298	Sandy clay
305-9	Sand, free
305-9	Clay
307	Free sand
308-6	Hard clay
312-6	Free sand
313	Clay
327-6	Sand
331	Clay
336	Free sand
338	Clay
344	Sand, clay streak, 339

This well repaired and changed to 4" in 1942

SHEET NO. 46 LINE NO. 19

Standard Wholesale Phosphate Co.
Curtis Ave. & Aspen St.

Well No. 4 Size: 10 in. Depth: 339 ft. Elev.:
Driller: Shannahan Drilled: 1941

FORMATION	Distance from top rotary 8" diamond bit
Gravel	15' - 30'
Clay & gravel	63
Hard clay	68
Sand	72
White clay & gravel	82' 6"
Hard white clay, 28" , 24 min.	88
Very sandy	93' 6"
Hard clay, seems more like sandstone, 1' 9", per hour	109
Sandy clay 2' in 8 min.	125' 6"
Hard & soft clay 2', 25 min.	140' 5"
Hard clay 2', 1 hr.	144' (bit wooded with clay)
Clay softer, 47 min.	152
Harder 2' in 25 min.	173' 5"
Sandy	174'11"
Rock soft	175' 3"
Sandy 2' , 1 min.	184' 6"
Hard crust	184' 7"
Sand streaks crusts iron ore & red, 15 min.	189
Red clay, soft, 11 1/2 min.	198
Sandy 2 ft., 2 min.	212'
Clay 2', 9 min.	218
Sand, free 2', 3 min. gravel in this	226
White sandy clay, 4 min.	230
Sandy clay	234
Sand & gravel 2', 1 min.	248
Sandy clay	263
Sand 2', 1 min.	271
Free sand, 10 sec.	272
Free sand, 2 min., 1/2" gravel	291
Very sandy clay, white	294' 5"
Sand 2 1/2 min.	301
Red clay 2' in 15 min.	310
Sandy clay	317
Fine gravel 6 1/4 min.	326' 6"
Fine sand & gravel, 11 min.	338' 6"
Rock, 40 min.	338' 7 1/2"

There is wood in most all of these strata.

SHEET NO. 47 LINE NO. 7

Judge Stockbridge
Wagners Point (Now owned by the Shell Oil Co.)

Well No.: Size: Depth: 381 ft. Elev.:
Driller: Shannahan Drilled: 1908

Log

26 -	30'	Coarse gravel
	50	Blue clay
	70	Sand
	92	Clay
	116	Sand - little water
	140	Sandy clay, Fe strata
	150	Hard red clay
	162	Sand
	179	Blue clay
	181	Boulder
	206	Brown clay
	229	Hard clay, Fe crust
	230	Boulder
	244	Sandy clay
	255	Sand. Pumped water 50 gal. cased off
	259	White clay
	289	Sand, little water
	330	Clay
	342	Sandy clay
	351	Sand, little water
	356	White clay
	381	Coarse sand and gravel, water

SHEET NO. 48 LINE NO. 5

Texas Oil Co.
East Brooklyn

Well No. Size: 6 in. Depth: 392 ft. Elev.:
Driller: J. H. K. Shannahan Drilled: 1910

Material	Color	Hardness	Depth
Clay	Yellow	Soft	0 - 15
Mud	Black	"	28
Sand	White	"	35
Sandy-clay	"	"	45
Gravel	"	"	59
Clay	Reddish	"	63
Sandy-clay	White	"	67
Gravel	-	-	90
Sand	White	-	102
Clay	Red-white	Hard	107
Sandy-clay with iron ore		Hard & Soft	110

SHEET NO. 48 LINE NO. 5

Texas Oil Co.
East Brooklyn (Continued)

Material	Color	Hardness	Depth
Sand coarse with iron ore		Hard & soft	110-115
Clay	White	Hard	119
Sandy	Red	Free	123
Clay	White	Hard	128
Sand & clay	"	Free	135
Sand	"	"	140
Sandstone	"	Hard	148
Clay	Drab	Tough	168
Clay	"	Hard	170
Clay	"	Soft	179' 4"
Boulder	-	Hard	180' 3"
Clay	Drab	Soft	186'11"
Boulder	-	Hard	187' 1"
Clay	Drab	S & H	208
Sand			225
Clay	Drab	Soft	228
Sandy-clay	White	Soft	248
Sand	Red	Free	265
Sandy-clay	White	Soft	293
Sand	Red	Free	307
Clay	White	Soft	332
Sandy-clay	White	Soft	367
Gravel			369
Clay	White	Soft	373
Gravel	"	"	387
Clay	Yellow	"	391' 7"
Rock			391' 7"

373-387 Same as Davison's

SHEET NO. 49 LINE NO. 14

U. S. COAST GUARD DEPOT
Curtis Bay, Maryland

Well No. Size: Depth: 192.62' Elev.: 22 ft.
Driller: Drilled:

Log

G. L. - 28'	Sandy clay
62.85	Hard white clay
82.65	Sandy clay - brown streaks
88	White sand drilled hard
89.5	Hard clay
93	Hard sand
97	Very hard clay

SHEET NO. 49 LINE NO. 14

U. S. Coast Guard Depot
Curtis Bay, Maryland (Continued)

Log

97 - 113	Fine sand
123	Hard & soft streaks
134	Sand & gravel - good
140	Hard & soft streaks
143.6	Free brown sand
146	Hard brown sand
147	Hard white clay
152	Hard sand
154	Sandy clay
161	Hard white clay
164.75	Sandy clay
165.25	Hard place
167.75	Sandy clay
167.85	Hard place
169.25	Sandy clay
175.75	Hard clay
178.75	Harder clay
179	Sand
182.25	Free brown sand
184	Very hard red clay
193	Large gravel & sand water bearing stratum
195	Clay

Screen placed at 185.37 - 192.62

SHEET NO. 50 LINE NO. 11

U. S. Industrial Alcohol, Co.
Curtis Bay, Maryland

Well No. 749 Size: Depth: 279-295 ft. Elev.:
Driller: Shannahan Drilled: 1917

Log

0 - 5	Sand & gravel
25	Sand
60	Clay
68	Sand
84	clay
90	Sandy clay
111	Sand
112	Clay
134	Sand
158	Sandy clay
164	Sand
173	Water sand

SHEET NO. 50 LINE NO. 11

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland (Continued)

Log

173- 180	Red clay
209	Sandy clay
228	Sand
234	Clay
260	Sandy clay
262	Gravel
272	Sandy clay
298	Water sand
302	Sandy clay

SHEET NO. 50 LINE NO. 13

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No. 751 Size: Depth: 289-305 ft. Elev.:
Driller: Shannahan Drilled: 1/1917

Log

0 - 15'	Sand & gravel
16	Fine sandy white clay
23	Sand & gravel
27	White clay
49	Hard sand
74	Clay
84	Sand
108	Red clay
122	Sandy clay
137	Sand
160	Sandy clay
201	Red clay
201-9	Rock
209-5	Sandy clay
209-11	Rock
231-6	Clay
232-4	Rock
235-7	Clay
236	Rock
236-8	Sandy clay
237-3	Rock
238-7	Sand
253	Sandy clay
253-4	Rock
255-5	Sand
255-9	Rock
260-2	Clay with rocks
273-9	Sandy clay

SHEET NO. 50 LINE NO. 13

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland (Continued)

Log

273-9 -	277-6	Sandy clay
	279-6	White clay
	285-4	Sandy clay
	304-2	Free sand
	309-4	Sandy clay

SHEET NO.50 LINE NO. 15

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No.: 1154 Size: Depth: 431 Elev.:
Driller: Drilled: 5/1920

Log

5	Sand & gravel
25	Sand
60	Clay
68	Sand
84	Clay
111	Sandy clay
112	Clay
134	Sand
158	Sandy clay
164	Sand
173	Water sand
180	Red clay
209	Sandy clay
228	Sand
234	Clay
260	Sandy clay
262	Gravel
272	Sandy clay
298	Water, sand
302	Sandy clay
312-6	White sand with water
316-6	Hard white sandy clay
324-9	Water sand
327-9	Clay
334	Sand white
335	Clay
341-6	Free sand
347	Red clay

SHEET NO. 50 LINE NO. 15

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland (Continued)

Log

347- 354	Clay with sand streaks
357-6	Red clay hard
386	Gray and white clay with wood and sand streaks
395	White clay
401	Soft formation of granite having mica and some gravel
425	Same formation without gravel getting harder
431	Rock quite hard

SHEET NO. 50 LINE NO. 17

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No. 1324 Size: Depth: Elev.:
Driller: Drilled: 1923

Log

0 - 10	Mixed earth
57	Sand & gravel
66	Clay
78	Sandy clay
89	Hard clay
99	Sandy clay
103	White clay
122	Water sand
132	White clay
142	Red clay, some iron
178	Red clay
178.5	Boulder
193' 4"	Gray clay
194	Boulder
196	Red clay
228	Sand
244	Clay
295	Water sand, water heads 59', 228 gpm:

SHEET NO. 50 LINE NO. 18

U. S. Industrial Alcohol. Co.
Curtis Bay, Maryland

Well No. 1325 Size: Depth: 228 ft. Elev.:
Driller: Drilled: 1923

Log

0 - 10	Mixed earth
21	Gravel
33	Hard white clay
51	Gravel
52	Boulder
62	White clay
67	Sand & gravel
74	White sandy clay
79	White clay
81	White sandy clay
89	Hard white clay
99	White sandy clay
122	White sand (80 gpm)
137	White clay
143	Red clay
149	Gray clay
176	Red clay 176-3 - - 176-10, boulder
182 1/2	Gray clay
193	Boulder
195	Red clay
228	Sand & gravel, water heads 57' - - 200 gpm

SHEET NO. 50 LINE NO. 19

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No.: 1326 Size: Depth: 327 ft. Elev.:
Driller: Drilled: 1923

Log

0 - 26	Mixed earth
34	Clay
53	Sand & gravel
54	White clay
67	Sand & gravel
72	White clay
78	Sand
80	Sand with hard clay
96	Sand, gravel & water
102	Clay
120	Water & sand
127	Clay
134	Red clay
138	Sandy clay
144	Red clay
149	Gray clay
180	Stone
190	Clay
191	Stone
194	Clay
196 1/2	Stone
200	Clay
219	Sand & clay
244	Water & sand
252	Clay
258	Sandy clay
284	Sand, lost water
285	Clay
299	Water sand
301	Clay
306	Sand
311	Clay
336	Water

Stopped on clay

SHEET NO. 50 LINE NO. 22

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No.: 2540 Size: Depth: 118-138 ft. Elev.:
Driller: Drilled: 1935

Log

38 -	39'	Clay
	40	Sandy
	65	Sand & clay
	67	Clay
	90	Large gravel
	99	Hard white clay
	103	Sandy
	118	Reddish sand free
	130' 9"	Fine sand
	131' 2"	Clay
	141' 2"	Free sand
	143' 9"	Clay

SHEET NO. 50 LINE NO. 23

U. S. Industrial Alcohol Co.
Curtis Bay, Maryland

Well No.: 3700 Size: Depth: 227 ft. Elev.:
Driller: Shannahan Drilled: 1939

Log

0 -	54'	Hard
	77	Sand, gravel & clay
	90	Hard clay
	111	Sandy clay
	111' 2"	Hard place
	133	Sandy clay
	138	Very hard, 9:30 PM to 2:20 AM
	140	Hard clay
	140' 6"	Hard 15 min.
	147' 5"	Streaky
	179' 5"	Clay
	181' 4"	Hard boulder. 8:45 AM 9:25
	194' 2"	Clay
	195' 2"	Boulder
	198	Sandy clay
	226	Sand

SHEET NO. 50 LINE NO. 24

U. S. Industrial Alcohol Co.

Well No.: New 3929 Size: Depth: 300 ft. Elev.:
Driller: Shannahan Drilled: 1940

Log		Log	
0.44	Sand, clay, sand & gravel	187	Sandy clay
65	Free sand	193	Sandy
66	Clay	193' 4"	Rock
69	Gravel & sand	193'11"	Sand
70	Clay	194	Rock
72	Sand	196	Sand
72' 6"	Clay	202	Sandy clay
77	Fine gravel	202' 1"	Rock
84' 6"	Hard clay	202' 6"	Sand
85' 6"	Sandy clay	204' 4"	Crusty rock
88' 6"	Free sand	204'10"	Clay
91' 6"	Clay hard 92' 6" clay hard	207	Rock
104	Free sand	209	Sand
105	Sandy clay	209' 5"	Rock, hard
107	Sand	211	Rock, softer, crusty
116	Sandy clay	214' 9"	Free sand
122' 6"	Free sand	215' 6"	Crusty
123' 6"	Clay 129' 6" sandy clay	227	Sandy
148' 8"	Red clay, hard	243	Free sand
159' 8"	Sandy clay	255' 5"	Sandy
166' 3"	Clay	274' 8"	Free sand
174' 3"	Hard red clay	275' 5"	Rock
		280' 1"	Free gravel
		280' 3"	Clay
		288	Free gravel
		299	Free sand
		300' 6"	Hard red clay

SHEET NO. 51 LINE NO. 19

U. S. Industrial Chemical Co.
Chem. Plant, Fairfield, Md.

Well No. 5023 # 1 Size: 16 in. Depth: 306 ft. Elev: 10-15 ft.
Driller: Shannahan Drilled: 1936

Log

0 - 16'	Yellow & gray clay
35	Large gravel
40	White sand
54	White clay tough & sand streaks
60	Free sand white
66	White sandy clay
76.85	Free white sand
76.85 80.00	Hard place 6", 10 min. 4 1/2" bit
100	Sandy clay, some hard
113	Free sand white
153.2	Red clay
154.4	Hard 13" 1/2 hr. 4 1/2 bit
157.5	Sand
182	Crust, then free sand, some coarse sand in it
213	Sandy clay
216	Hard clay white
218	Free sand white
224	Sandy clay
226	Hard clay
227	Clay
242	Sand with some very coarse gravel in it
243	Clay
249	Gravel free, lost good bit of mud
258	Hard white clay
261	Sand free
269.7	Clay & sand streaks
271	Hard clay
276	Softer clay, white
306	Hard clay

SHEET NO. 51 LINE NO. 20

U. S. Industrial Chemical Co.
Chem. Plant, Fairfield, Md.

Well No.: 6842 #2 Size: Depth: 360.5 ft. Elev.: 10-15 ft.
Driller: Shannahan Drilled: 1938

Log

20	Clay
40	Gravel
64	Hard clay
66	Sand
80	Hard clay
92' 6"	Sandy, free
94' 8"	Hard sand
107' 5"	Sand free
111	Hard sand
127' 5"	Softer
168' 4"	Hard clay
171' 4"	Iron ore, hard
179	Sand, not free
180	Hard
199	Sandy, free in places
201	Hard place
215	Sandy, not free
247'10"	Harder
248'10"	Yellow sand, free
253' 7"	Red sand, free
253' 8"	Hard iron ore
257	Red sand, coarse, free
258	Clay
267' 4"	Sand & gravel
268	Hard iron ore
269' 7"	Sand & gravel
274	Hard iron ore
290	Sand, not so free
304	Hard clay
305	Harder
310	Sandy clay
318	Blue clay
334	Sand
344	Sand, free in places
354	Gravel
356	Streak of clay
361	Top of bed rock

	August 1939
Cl	9
Hardness	10.6
pH	5

SHEET NO. 52 LINE NO. 11

U. S. Revenue Cutter Service
Arundel Cove, Anne Arundel County

Well No.: Size: 6 in. Depth: 198 ft. Elev.: 15 ft.
Driller: Shannahan Drilled:

Log

0 - 5	Clay yellow soft
12	Sand yellow soft
16	Clay blue soft
19	Sand yellow soft
26	Mud black soft
35	Sand white soft
60	Clay red white hard
78	Clay red hard
88	Sandy-clay white soft
122	Sand white free
125	Sand brown free
135	Sand white free
140	Sandy-clay white soft
144	Sandstone white hard
170	Sandy clay white soft & hard
172	Sandstone very hard
177	Sandy clay white soft
181	Rock very hard
183	Clay white hard
189	Sand-gravel white free

SHEET NO. 53 LINE NO. 14

C. E. Weaver
Harford Road, Nr. Weber Park

Well No. Size: 6 In. Depth: 203 ft. Elev.:
Driller: C. Hoshall Drilled: 1907

Log

0 - 40	Yellow sandy clay
55	Quicksand
80	Coarse sand & gravel
203	Mica rock: cuts nicely

SHEET NO. 53 LINE NO. 15

H. A. Weaver
Harford Road Nr. Weber Park

Well No.: Size: 6 in. Depth: 112 ft. Elev.:
Driller: Clark Hoshall Drilled:

Log

0 - 44'	Yellow sandy clay
55	Quicksand
70	Coarse sand & gravel
100	Very hard rock
112	Very soft rock
	Very hard rock

SHEET NO. 54 LINE NO. 3

Weiskittle Foundry
Lombard & 8th Street

Well No.: Size: 6 In. Depth: 263 ft. Elev.:
Driller: Drilled: 1903

Log

150 - 200'	Sand & gravel white (Potomac)
204	Potomac to gneiss
245	Gneiss
250	"
263	Gneiss with much muscovite & garnet

SHEET NO. 54 LINE NO. 8

Western Electric Co.
Point Breeze

Well No.: 2 Size: Depth: 294 ft. Elev.:
Driller: Layne Atlantic Drilled: 1930

Log Elevations referred to M.L.W. as 0.00

+8.05	- 3		Fill
	7		Clay
	18		White sand
	54	R	Red clay
	65		Sandy clay
	90		Blue clay
	108		Fine sand
	192		Buck shot clay
	214		Soft red clay
	240		Hard clay
	260		Brown clay

SHEET NO. 54 LINE NO. 8

Western Electric Co.
Point Breeze

Well No.: 2 (Continued)

Log

260	- 266	Red clay
	304	Sand & gravel
	313	Red clay

SHEET NO. 54 LINE NO. 7

Western Electric Co.
Point Breeze

Well No. 1 Size: Depth: 301 ft. Elev.:
Driller: Layne Atlantic Drilled: 1930

Log Elevations referred to M.L.W. as 0.00

+8.05	- 102	Sand, clay & gravel
	117	Hard red clay
	151	Hard yellow sandy clay
	161	Hard sand & gravel
	177	Fine brown sand
	181	Sand & gravel
	200	Hard soapstone
	202	Hard sand
	207	Soft red clay
	223	Hard pan
	233	Hard sand
	237	Clay
	258	Sand & gravel
	262	Clay
	301	Sand & gravel

SHEET NO. 54 LINE NO. 12

Western Maryland R.R.
Near Hanover & McComas Streets

Well No.: Size: Depth: 60 ft. Elev.:
Driller: Drilled:

Log

+3	- 0	Earth
	15	Gravel
	21	White sand
	23	Brown clay
	47	Red clay & iron
	57	Fine sand

APPENDIX IV

Computation of Pressure Relief in Horizon B

In order to compute the pressure relief in Horizon B at various distances from Sparrows Point, Maryland the following assumptions are made.

1. The whole of Sparrows Point functions as a single well with an estimated diameter of 2000 feet.

2. The average drawdown at Sparrows Point is 150 feet when the drawdown at the Bay Shore Park well three miles east is 68 feet.

3. The aquifer is unlimited in extent and uniform in thickness and permeability.

Assuming Darcy's law applies, the velocity in the aquifer at any point around the well field is proportional to the slope of the pressure relief curve at that point. Using this fundamental law the relation between the distance from the well and the amount of relief is derived as follows.

Let:

Q = flow toward well through any pie-shaped segment of the aquifer.

K = coefficient of permeability.

a = cross-sectional area of pie-shaped segment at any distance x from the well.

s = slope of the drawdown curve.

t = thickness of segment.

h = drawdown, or pressure relief.

x = distance from the well.

R = radius of the circle of influence.

C_1, C_2 and C_3 = constant.

Darcy's law: $$Q = K\,a\,s$$

$$a = C_1 \pi\, x\, t$$

$$s = \frac{dh}{dx}$$

$$Q = K\,C_1\,\pi\,t \times \frac{dx}{x}$$

$$dh = -\frac{Q}{K\,C_1\pi t}\;\frac{dx}{x}$$

$$\text{Let} \quad \frac{Q}{K\,C_1\pi t} = C_2$$

$$dh = -C_2\,\frac{dx}{x}$$

$$h = -C_1\,\text{Log}_e\,x + C_3$$

changing logs and rewriting

$$h = -a\,\text{Log}\,x + b$$

when $x = 2000$ ft. $\quad h = 150$ ft.

when $x = 16000$ ft. $\quad h = 68$ ft.

$$\begin{array}{rcl} 150 & = & -a\;3.301 + b \\ 68 & = & -a\;4.204 + b \\ \hline 82 & = & a\;.903 \end{array}$$

$$a = \frac{82}{.903} = 90.8$$

$$b = 150 + 90.8 \times 3.301 = 450$$

$$\text{Thus} \quad h = -90.8\ \text{Log}\,x + 450$$

This equation is used to compute the pressure relief h, for assumed values of x shown in Table XI page 39.

When $h = 0$ $x = R$ = radius of the circle of influence.

$$\text{Log}\,R = \frac{450}{90.8} = 4.96$$

and $R = 91{,}200$ feet

or $R = 17$ miles

APPENDIX V

Computation of the Distance from the Foot of Riser Pipe to a Casing Leak

When high chloride water is entering through a casing leak below the foot of the riser pipe the leak may be located by pumping and chloride testing after a period of shut-down. The distance from the foot of the riser pipe to the casing leak may be computed as follows:

Let Q = the rate of pumping in g.p.m.; D, the casing diameter in inches; d, the riser pipe diameter in inches; t, the time in seconds between the first appearance of water at the surface and the sharp rise in chlorides; L, the length of the riser pipe; H, the static level measured from the surface; h, the dynamic level measured from the surface, and X, the distance from the foot of the riser pipe down to the leak, all vertical distances measured in feet. See Figure 30.

Equating the volume pumped before the appearance of high chlorides to the volume of fresh water that must be displaced to draw contaminated water to the surface the following expression is obtained:

$$\frac{Qt}{7.48 \times 60} = \frac{\pi D^2}{4 \times 144}(h - H + X) + \frac{\pi d^2}{4 \times 144}(L-h)$$

The significance of this equation is as follows:

(Volume of water pumped before first rapid increase in chlorides.)	=	(Volume of water in casing between static and dynamic levels and between foot of riser and the leak.)	+	(Volume of water in riser between dynamic level and foot of riser pipe.)

The above equation reduces to

$$0.408\, Qt = D^2 (h-H) + d^2 (L-h) + D^2 X$$

from which $X = \dfrac{0.408\, Qt}{D^2} + \dfrac{d^2}{D^2}(L-h) + (h-H)$

When the pump is started the water rises in the casing below the pump intake as the free water surface outside the riser pipe falls. If the leak is close to the foot of the pump intake salty water may flow up the riser before the full drawdown has developed and the results will be somewhat in error.

If the leak is above the lower end of the pump intake the above equation will not apply and the volume of water pumped before the appearance of high chlorides will equal the internal capacity of the riser

pipe from the static level downward. That is

$$\frac{Qt}{7.48 \times 60} = \frac{\pi d^2}{4 \times 144} (L - H)$$

(Volume of water pumped before first rapid increase in chlorides.) = (Volume of water in the riser pipe below the static level)

In this case it is impossible to locate the level at which the casing is leaking by the pumping and chloride testing method.

If X equals the distance from the foot of the pump intake to a point not far above the top of the screen, leakage outside the casing should be suspected.

If the equation for X gives a value considerably greater than the distance from the foot of the intake to the bottom of the well, then the leakage is at a nearby well or gravel conductor. In this case the volume of water that must be removed from outside the screen in order to draw leakage water into the well is equal to the difference between the left and right hand members of the first equation, when X is set equal to the depth of the well less the length of the riser.

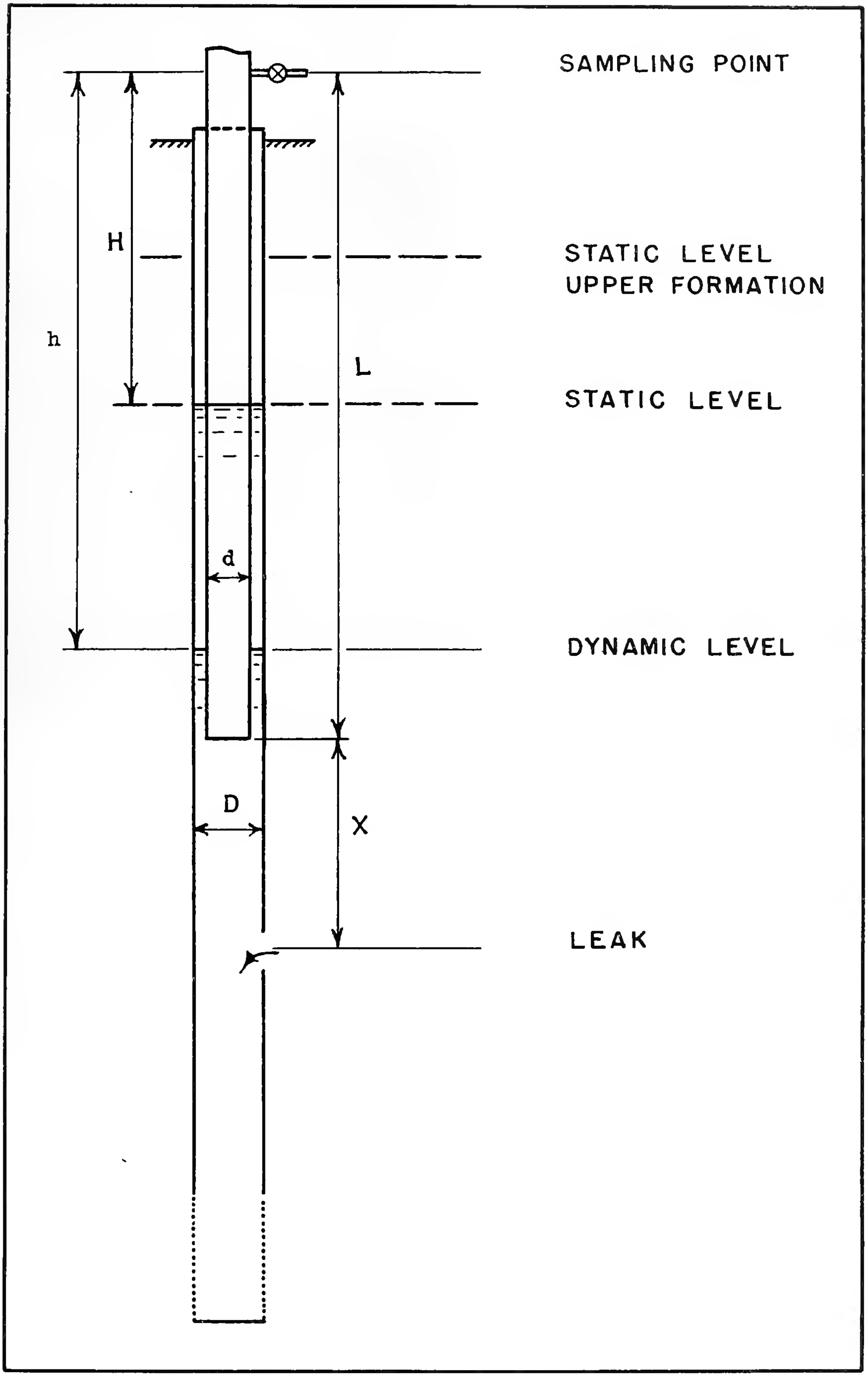


Fig. 30 Symbols Used in Computing the Distance from Foot of Riser Pipe to Leak.

APPENDIX VI

The Effect of Variations in Pumping Rates on Chloride Content in a Leaking Well

The following computations show the effect of different pumping rates on the chloride content of the mixture of contaminated and fresh water withdrawn after all the shutdown leakage has been flushed from a well. Calculations are also presented to show how the amount of leakage may be determined if the natural chlorides for the two aquifers involved are known.

The assumed conditions are as follows:

Upper Aquifer: Static head 100 feet below the surface, drawdown due to leakage negligible, and chloride content of the shallow water 2000 p.p.m.

Lower Aquifer and Well: Static head 175 feet below surface, specific delivery 20 gallons per minute per foot of drawdown and natural chloride content of fresh water 10 p.p.m.

It is assumed further that when the well is pumped at a rate of 200 g.p.m. the chlorides in the water delivered is 160 p.p.m.

The problem is to determine the expected chloride content of the water if the well is pumped at 600 g.p.m.

Let Q_1 and Q_2 be the fresh water flows

and q_1 and q_2 the leakage from the upper aquifer,

then $Q_1 + q_1 = 200$ g.p.m., (a)

and $Q_2 + q_2 = 600$ g.p.m., (b)

If the drawdown at 200 g.p.m. is 10 feet the drawdown at 600 g.p.m. will be approximately 30 feet.

Let H_1 and H_2 be the heads that produce fresh water flow, that is, the drawdowns of 10 and 30 feet.

and h_1 and h_2 the heads that produce leakage

$$h_1 = 175 + 10 - 100 = 85 \text{ feet}$$

$$h_2 = 175 + 30 - 100 = 105 \text{ feet}$$

Leakage water will probably enter casing perforations or move down leaks outside the casing in turbulent flow. For turbulent flow the leakage will vary as the square root of the head difference across the leak. Therefore:

$$\frac{q_1}{q_2} = \sqrt{\frac{85}{105}} \text{ or } 1.11\, q_1 = q_2 \qquad (c)$$

If the chlorides in the upper formation are not known there is no way to figure the proportion of fresh and leakage water at the 200 g.p.m. pumping rate or the true ratio of Q_1 to Q_2, so equations (a) and (b) cannot be solved. However, if it can be assumed that the proportion of leakage water is small, Q_2 will be approximately $3Q_1$ and the chlorides at the second pumping rate can be calculated as follows:

$$\frac{q_1}{Q_1} = \text{ ratio of leakage to fresh water at 200 g.p.m.}$$

$$\frac{1.11\, q_1}{3Q_1} = \text{ ratio of leakage to fresh water at 600 g.p.m.}$$

since the chlorides of the mixture, less the natural 10 p.p.m. will vary with the dilution ratios the chlorides at 600 g.p.m. will be:

$$(160-10)\ \frac{1.11}{3} + 10 = 65.5 \text{ p.p.m.}$$

If the proportion of leakage water entering the well in turbulent flow is large this will be evidenced by the fact that the specific delivery will not be constant. Furthermore, in this case, since the q's are large, the ratio of the Q's will be considerably increased and the chlorides will actually decrease more rapidly with the larger pump rates. This is due to the fact that with high leakage rates practically all the water at low pump discharges comes from the leak and the relative increase in fresh water is great when the pumping rate increases. Or since the leakage is relatively constant compared to the aquifer flow, the increase in dilution ratio will be greatest in the range where fresh water is first pulled into the well. Furthermore, the pumping rates at which this is true increase with the leakage rate.

Now assuming that the chlorides have been determined as 2000 and 10 p.p.m. respectively in the upper and lower strata, the ratio of leakage to fresh water can be computed from the 160 p.p.m. in the mixture.

$$\frac{q_1 \times 2000 + Q_1\, 10}{q_1 + Q_1} = 160$$

$$2000\, q_1 - 160\, q_1 = 160\, Q_1 - 10\, Q_1$$

$$\frac{Q_1}{q_1} = \frac{1840}{150} = 12.3 \qquad (d)$$

Using equations (a), (b), (c) and (d) both values of q and Q can be computed.

$$Q_1 - 12.3\ q_1 = 0$$

$$\frac{Q_1 + q_1 = 200}{13.3\ q_1 = 200} \qquad q_1 = 15 \text{ g.p.m.}$$

therefore $Q_1 = 200 - 15 = 185$ g.p.m.

$q_2 = 1.11 \times 15 = 16.7$ g.p.m.

and $Q_2 = 600 =-16.7 = 583.3$ g.p.m.

The chloride content at the 600 g.p.m. pumping rate will therefore be:

$$\frac{16.7 \times 2000 + 583 \times 10}{600} = 65.5 \text{ p.p.m.}$$

This checks the value estimated on page 202 and illustrates the fact that the effect of increased pumping rate on the chlorides can be accurately estimated without knowing the leakage rate or the chlorides in the leakage water so long as the rate of leakage is small in proportion to the rate of pumping. It should be noted that the head difference across the leak must be known. Although this can seldom be measured, inaccuracies in assumed static head at the source of leakage have relatively little effect on the computations. For example, had a static level of 50 feet rather than 100 feet been assumed for the upper formation the estimated chlorides in the mixture at the 600 g.p.m. pumping rate would have been found as follows:

$$\frac{q_1}{q_2} = \sqrt{\frac{135}{155}} \text{ or } 1.07\ q_1 = q_2$$

using this value

$$(160 - 10)\ \frac{1.07}{3} + 10 = 63.5 \text{ p.p.m.}$$

The difference is 2 p.p.m. for a static head change from 100 feet to 50 feet.

Since the relative change in heads across the leak are always smaller than the relative head change on the main aquifer, chlorides will always drop with increasing pump rates. If the leak is small, the effect on chlorides will be approximately the same for either laminar or turbulent flow through the leak. When laminar flow prevails, the leakage varies directly with the increase in head.

APPENDIX VII

Chloride Calculations and Tests

The calculations and measurements of resistivities of pure sodium chloride solutions which were made in connection with chloride studies are described here.

Definitions of terms and equations used are as follows.

Specific Resistance, r, is the resistance of a unit centimeter cube expressed in ohms.

Specific Conductivity, K, is the reciprocal of specific resistance.

Equivalent Conductivity, M = KV, where V is the volume of solution containing one gram equivalent of the solute. At high dilutions an almost constant M is reached. Values for concentrations of 0.5 mil-equivalents (.0005 N) are approximately the same in many cases. Values of quivalent conductivity in reciprocal ohms for various mil-equivalent per liter concentrations of the salts commonly found in natural waters are given in Table XIX. This table has been condensed from those of Washburn and Klemeno in the "International Critical Tables".

Equations:

$$K = \frac{1}{r} = \frac{L}{Ra} = \frac{LI}{Ea}$$

where: K is the specific conductivity; r, the specific resistance in ohms; L, the length of current path in cm.; a, the area of current path in ohms; E, the electrode potential difference in volts; and I, the current in amperes. The conductivity and resistivity change with temperatures according to the following equations:

$$K_t = K_{18} \left[1 + b\,(t - 18)\right]$$

and $$r = \frac{r_{18}}{\left[1 + b\,(t - 18)\right]}$$

where: K is the specific conductivity at any temperature t in C°, K_{18}, the specific conductivity at 18°C; and b, the coefficient that depends on the salt and its concentration.

b = 0.02 to 0.025 for salts and bases

b = 0.01 to 0.016 for acids

For pure dilute NaCl solutions b = 0.25 approximately and decreases slightly with increasing concentration. Thus the increase in

TABLE XIX

Equivalent Conductivities of Common
Salts, Acids and Bases
Found in Ground Water

Chem.	Temp. °C	Mil-equivalents					Per		Liter			
		.5	1	2	5	10	20	50	70	100	200	500
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
NaCl	(18	106.95	106.27	105.31	103.54	101.72	99.4	95.51		91.82	87.53	80.76
	(25	125.0	124.1	123.0	120.8	118.6	115.8	111.0	109.0	106.6	101.5	93.31
1/2 $CaCl_2$	18	113.18	111.8	109.92	106.55	103.23	99.24	93.16	90.75	88.07	82.68	74.82
1/2 $MgCl_2$	25		127.2	124.4	120.3	116.6	112.2	(106)	(103)	(101)	(94)	(84)
1/2 Na_2SO_4	(18	107.3	105.8	104.1	100.2	96.1	91.0	83.68	80.9	77.6	70.4	59.4
	(25			122.1	117.28	112.39	106.8	97.8	94.2	90.0	81.54	
1/2 $MgSO_4$	(18	104.2	99.9	94.2	84.3	76.0	67.5	56.7	53.2	49.57	43.0	34.8
	(25	123.2	117.6	110.9	98.8	88.9	79.0	66.5	62.2	57.8	49.8	40.7
1/2 $CaSO_4$	(18	109.2	103.9	97.1	86.4	77.42	68.3					
	(25	127.2	121.4	115.0	100.0	90.0	79.2					
1/2 $FeSO_4$	25		113.4	104.6	92.3	82.5	72.7	60.1	55.7	51.4	43.9	35.3
Ca $(HCO_3)_2$	25	203	199	195	189	183	172.5	153.5	146	137.2	119.6	
Mg $(HCO_3)_2$	25				179	172	160	142		127		
Na HCO_3	25	94.4	93.5	92.5	90.3	88.1	85.5	80.6	78.5	76.1		
1/2 H_2SO_4	25	413.1	(399.5)	390.3	(364.9)	336.4	308.0	272.6	261.5	250.8	234.3	222.5
1/2 H_2SO_4	18	371.3		353.4		308.6		253.1	243.5	252.9		
HCl	18		377	375.3	372.4	369.3	364.9	357.6	354.1	350.1	341.5	326.6
1/2 Ca $(OH)_2$	25				226	220	210					
NaOH	18			213.5	210.8	208.4	205.5	200.3	198.0	195.3	189.0	175.5

conductivity is about 2.5 per cent per degree centigrade in dilute solutions at normal temperatures.

Since $M = KV$ and $K = \frac{1}{r}$

it follows that

$$M = \frac{V}{r} \text{ or } r = \frac{V}{M}$$

Calculations:

Using the above equations and the values of M given in Table XIX, the resistivity of electrolytes at various concentrations may be calculated as follows: Assume solution contains a given amount of salt expressed in p.p.m. The mil-equivalent per liter, C, of this solution is:

$$C = \frac{(\text{p.p.m.})}{\text{Equiv. wt. of salt}}$$

and the ml. volume of solution containing 1 gm equivalent weight of the salt is:

$$V = \frac{\text{equiv. wt. of salt}}{(\text{p.p.m.})} \times 10^6$$

The equivalent conductivity M in reciprocal ohms is taken from Table XIX for the values of C, and the resistance in ohms calculated from the equation:

$$r = \frac{V}{M}$$

Solutions containing arbitrary amounts of NaCl in distilled water were made up and tested for chloride content and resistivity at the Montebello filter plant using the laboratory standard silver nitrate solution. Temperatures of the solutions were not accurately measured but were approximately 25°C. The resistance was determined with an Industrial Instruments Company, Model RC, conductivity Bridge and a conductivity cell whose constant was 0.998. This equipment was loaned by the Bethlehem Steel Company. It is a wheatstone bridge which gives the resistance in ohms. The cell constant has been assumed to be 1.0 in the following calculations. The measured chloride ion contents and resistances are shown in Table XX.

Resistances for the measured amounts of chloride ion stated in Table XX are calculated for 18°C and 25°C. Computations are shown in Table XXI and the measured resistances are repeated for comparison with the calculated values. See columns (8) and (9) Table XXI. The discrepancies between the calculated and measured resistivities may

TABLE XX

Measured Concentration and Resistance of
Pure Salt Solutions Containing Various
Amounts of Chloride Ion

Solution No.	Cl^- p.p.m.	Resistance ohms	Temp. °C
1	10500	32	25 ±
2	2100	160	25 ±
3	1050	315	25 ±
4	205	1450	25 ±
5	104	2800	25 ±
6	41	6800	25 ±
7	24	11700	25 ±
8	11	23000	25 ±

TABLE XXI

Calculation of Resistance of Pure Salt Solutions and Comparison with Measured Values

Sol. No.	Chloride Ion Cl^- p.p.m.	Mil-equiv. per liter C	Ml. of solution containing 1 gm. equiv. V	Equivalent Conductivity Recip. ohms at 18°C M_{18}	Equivalent Conductivity Recip. ohms at 25°C M_{25}	Calculated Resistance at 18°C r_{18} ohms	Calculated Resistance at 25°C r_{25} ohms	Measured Resistance at 25°C approx. ohms
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	10500	296	3380	85.4	98.9	39.6	34	32
2	2100	59.2	16,900	94.7	110	178	154	160
3	1050	29.6	33,800	97.8	113.9	345	300	315
4	205	5.78	173,000	103.2	120.4	1670	1430	1450
5	104	2.93	341,000	104.7	122.2	3260	2690	2800
6	41	1.16	865,000	106.0	123.8	8160	7000	6800
7	24	0.68	1,480,000	106.6	124.1	13,900	11,900	11,700
8	11	0.31	3,230,000	107.2	125.5	30,100	25,700	23,000

Col. (3) $= \frac{\text{Col (2)}}{35.46}$; Col (4) $= \frac{35.46}{\text{col (2)}} \times 10^6$; Cols. (5) & (6) from Fig. 33

Col (7) $= \frac{\text{Col (4)}}{\text{Col (5)}}$; Col (8) $= \frac{\text{col (4)}}{\text{col (6)}}$; Col (9) observed values.

be due to slight temperature variations among the different salt solutions tested and to errors in judging the correct end point in the chloride titration. In any event the above calculations and tests indicate that both the resistivity measurements and the chloride analysis procedures used were sufficiently accurate for all practical purposes. The calculated values of specific resistance of pure sodium chloride solutions were plotted in Figure 8, page 62 , to be used for comparisons in further work.

APPENDIX VIII

Theory of Geochemical Analyses 16/ 17/

Geochemical analyses require a knowledge of the amounts of the various ions present in the waters studied. In the chloride and resistivity test described above, only the ratio of the chloride ions to the balance of the anions in solution are taken into account. Figure 8, therefore, represents about the simplest geochemical chart that can be conceived. The most elaborate geochemical studies take into consideration the amounts of every type of ion present.

In all geochemical analyses the amount of each ion present must be expressed in terms of its electric or equivalent value. The common practice is to use mil-equivalents per liter as a measure of the ion concentrations. The mil-equivalents are readily calculated by dividing the concentration expressed in parts per million by weight, by the equivalent weight of the ion. Care must be taken in making these conversions when the ion concentration is expressed in terms of a salt. For example, it is common practice to express the bi-carbonate ion concentration in terms of calcium carbonate. The conversion is figures from the chemical equation:

$$\underset{100}{CaCO_3} + CO_2 + H_2O \rightleftharpoons Ca^{++} + \underset{\underset{122}{2\,(1 + 12 + 48)}}{2\,HCO_3^-}$$

Thus one molecule of calcium carbonate is the equivalent of two bicarbonate ions. Two parts per million of bicarbonate ion are:

$$\text{p.p.m. } CaCO_3 \times \frac{122}{100} = \text{p.p.m. } HCO_3^-$$

and the equivalent concentration of bicarbonate is:

$$\text{Mil-equivalents } HCO_3^- = \frac{\text{p.p.m. } HCO_3^-}{61}$$

The ions present in natural water may be classed as follows:

16/ Chase Palmer, "The Geochemical Interpretation of Water Analyses" U. S. Geological Survey Bulletin No. 479, 1911.

17/ Raymond A. Hill, "Geochemical Patterns in Coachella Valley" American Geophysical Union Transactions 1940, Part I.

	Ions	
a	(Na^+) (K^+)	Primary cations due to alkalies. Negative non-carbonate hardness minerals.
b	(Ca^{++}) (Mg^{++}) (Fe^{++}) (Al^{+++})	Secondary cations due to Alkaline Earths. Hardness minerals.
c	(H^+)	Hydrogen ions. Considered only when free acid is present.
d	(Cl^-) (NO_3^-) (SO_4^{--})	Acid anions.
e	(CO_3^{--}) (HCO_3^-) (OH^-)	Alkaline anions Carbonate hardness ions

The following combinations of these ions which characterize various types of natural waters are:

Class (1)	($d < a$) ($e > b$)	Alkalinity greater than hardness. The negative non-carbonate hardness equals the alkalinity minus the hardness.
Class (2)	($d = a$) ($b = e$)	Alkalinity equals the hardness.
Class (3)	($d > a$) ($e < b$)	Alkalinity less than hardness. Non-carbonate hardness equals the hardness minus the alkalinity.
Class (4)	($d = a + b$) ($e = 0$)	Alkalinity is Zero.
Class (5)	($d > a + b$) ($e = 0$)	Free acid present and equals the acid anions minus the total cations.

Palmer 16/ states that surface waters belong to the first three classes, that class 4 is represented by sea water and brines and that class 3 is exemplified by mine waters.

16/ Chase Palmer, "The Geochemical Interpretation of Water Analyses" U. S. Geological Survey Bulletin No. 479, 1911.

Uncontaminated ground waters in the area seem to fall in class 2 or 3 and to lie close to class 2. Patapsco River water is certainly in class 4. Ground waters from acid contaminated areas in class 5. Analyses and mil-equivalent concentrations of ions are shown in Table XXII for Patapsco River water and for a few well waters. The values for the river water are complete and in balance. Those for Bethlehem Steel Company FH No. 2 are fairly complete but not in balance. The rest of the analyses shown are incomplete. However, the latter represent the best type of information available among the multitude of data on chemical tests of ground water in the area. The analyses cannot be checked by balancing the anions and cations because the primary cations have not been determined and must be estimated from the difference in the measured anions and cations.

Rectilinear Plotting.

In order that waters can be easily studied according to the above five classes and that the proportions of various water in mixtures can be readily ascertained the plotting method described below was devised. Whether the scheme presented here has been used before is not known.

Using the first two analyses in Table XXII as examples, the percentage of primary and secondary cations to the total cations, and percentage of acid and alkaline anions to the anions are figured as shown in Tables XXIII and XXIV. When free acids are present both the hydrogen ion of the free acid and the total acid and the total anion are figured as a per cent of the total cations.

Using the rectilinear graph shown in Figure 31 the cations are plotted on the abscissa and the anions on the ordinate. Free acid plots in a negative direction on the alkalinity scale. Reference to the definitions of the five classes shows that Class (1) waters will plot in the area above the diagonal, Class (2) waters along the diagonal, Class (3) below the diagonal, Class (4) along the abscissa and Class (5) below the abscissa.

Points for waters of various types are plotted in Figure 31, and numbered according to the column in Table XXII in which computations of ionic group percentages appear. Point No. 7 for Patapsco River water falls in Class (4) as expected. Point 5 for Filter House well No. 2 which is contaminated with acid and iron as well as with salt. Points 13 and 17 are for uncontaminated waters from the 230 to 250 Horizon at the Bethlehem Steel plant, while Points 19 and 21 are for uncontaminated water from 336 and 650 foot wells. The balance of the points represent salt contaminated waters. The analyses are not considered sufficiently accurate nor are there enough of them to make further interpretations. Since there has been a great deal of filling with slag on Sparrows Point the shallow ground water there must contain acids and other minerals in addition to the salts that come in with water from the river. This might explain the scatter of points representing contaminated well waters.

TABLE XXII

ANALYSES AND IONIC GROUP PERCENTAGES FOR
PATAPSCO RIVER WATER AND FOR WATER FROM SPARROWS POINT WELLS
FURNISHED BY THE BETHLEHEM STEEL COMPANY

		Equiv. Weights	Sample of River Water at New Pump Station		New Well at #2 F. H. 8/8/40		Sheet Mill #1- 177 ft. 10/3/39		Sheet Mill #2- 368 ft. 10/3/39		Hot Strip Mill #1 - 247 ft. 10/3/39		Hot Strip Mill #5 - 230 ft. 10/3/39		Hot Strip Mill #8 - 234 ft. 10/3/39		Hot Strip Mill #2 - 336 ft. 10/3/39		Hot Strip Mill #3 - 650 ft. 10/3/39	
			P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.	P.P.M.	Mils-Equivs.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
	pH		7.3				6.2		5.9		5.7		5.7		5.7		6.3		6.5	
	Free CO_2		6				40		35		19		16		23		23		40	
	Total Alkalinity		15				36		22		20		20		18		40		44	
(e) Alkaline Anions	CO_3^{-}	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	HCO_3^{-}	61	18.3	0.3	0	0	44	0.72	27	0.44	24.4	0.40	24.4	0.40	22	0.36	49	0.80	53.6	0.88
	OH^{-}	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total			0.3		0		0.72		0.44		0.40		0.40		0.36		0.80		0.8[illegible]
	Per Cent			0.15		0		5		6		41		17.4		36.4		61		60.7
(d) Acid Anions	Cl^{-}	35.5	6284	177	129.8	3.660	450	12.68	230	6.48	8	0.23	56	1.58	11.3	0.32	6	0.17	11.5	0.32
	SO_4^{--}	48	764	15.6		0.416	40.6	0.85	29.6	0.62	16.3	0.34	15.2	0.32	15.1	0.31	16.3	0.34	12.2	0.25
	NO_3^{-}	62	0																	
	Total			192.6		4.076		13.53		7.10		0.57		1.90		0.63		0.51		0.57
	Per Cent			99.95		107.6		95		94		59		82.6		63.6		39		39.3
(b) Hardness or Secondary Cations	Ca	20	1498	74.9	7.4	0.370	37.6	1.88	17.4	0.870	4.5	0.225	5.1	0.255	3.1	0.155	4.9	0.245	6.9	0.345
	Mg	12.2	400	33.3	6.6	0.550	22	1.81	7.2	0.590	0.4	0.032	2.2	0.181	0.6	0.049	0.8	0.065	1.1	0.090
	Fe	28	2.6	0.1	39.9	1.425	73.8	2.64	42.8	1.580	5.8	0.207	16	0.572	4.4	0.157	16.6	0.593	10.2	0.364
	Al	9	0.4	0.04	2.1	0.233													0.9	0.100
	Total			108.3		2.578		6.33		3.02		0.464		1.008		0.361		0.903		0.90
	Per Cent			56.4		68		44.4		40		48		43.8		36.5		68.9		62
(a) Primary Cations	Na	23	1666	72.4	27.9	1.212														
	K	39.1	454	11.6																
	Total			84.0		1.212		7.92		4.52		0.506		1.292		0.629		0.407		0.55
	Per Cent			43.6		32		55.6		60		52		56.2		63.5		31.1		38
(c)	Acid as HCl	36.5			21.6	0.592														
	Total Cations			192.3		4.382														
	Total Anions -			192.9		4.076		14.25		7.54		0.97		2.30		0.99		1.31		1.45
	SiO_2		10.7				16.8		2.5		5		10.7		6.2		9.3		8.2	

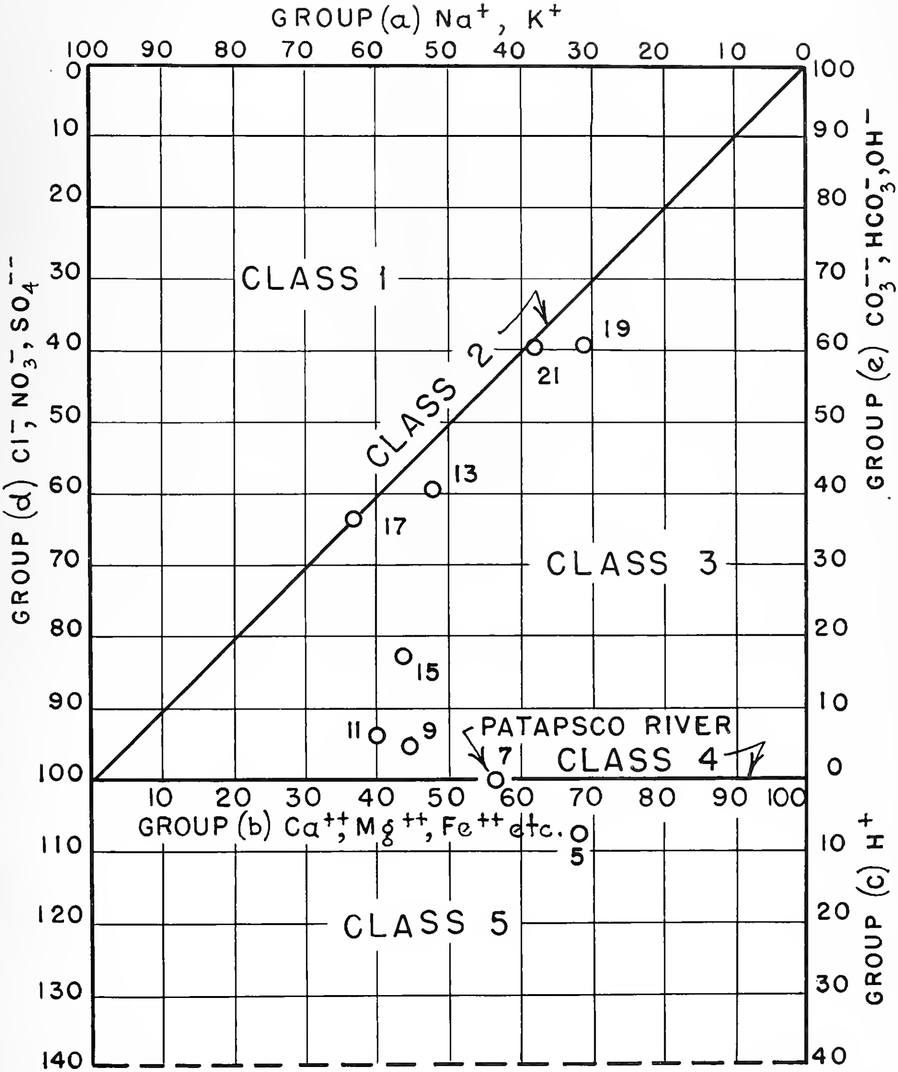


Fig. 31 Rectilinear Geochemical Graph.

TABLE XXIII

IONIC GROUP PERCENTAGES FOR SAMPLE OF RIVER WATER TAKEN AT NEW SALT WATER STEAM PUMP HOUSE BETHLEHEM STEEL COMPANY 11-20-39

Group	Milligram-Equivalents Per liter	Per Cent of totals
a	84	43.6
b	108.3	56.4
a + b	192.3	100
c	0	99.95
d	192.6	0.15
e	0.3	100
d + 2	192.9	

TABLE XXIV

IONIC GROUP PERCENTAGES FOR SAMPLE OF WELL WATER, FILTER HOUSE NO. 2 BETHLEHEM STEEL COMPANY 3-8-40

a	1.212	32.0
b	2.578	68.0
a + b	3.790	100
c	.286 *	7.6 **
d	4.076	107.6 **
e	0	0
d + e	4.076	107.6 **

* Arbitrarily changed to obtain balance.

** Expressed as percentages of (a + b)

The point for a mixture of two waters will plot on the line connecting the points representing the character of each water. The ratio of the distance between the point for the mixture and the points for one of the separate waters, to the total distance between the points for the constituent waters to the proportion of the water in the mixture. In the same way a mixture of several waters will plot in the polygon connecting points for the waters mixed and the location within the polygon is determined by the percentages of each water in the mix.

Therefore, if the character of waters in all the aquifers in each part of the Baltimore Industrial Area can be determined this method should be very useful in determining the source and amount of leakage by chemically analyzing the water in a contaminated well. The method might also prove very useful in correlating the aquifers of wells in different parts of the area.

The application of the method requires the following chemical analyses.

1. Either alkalinity or free mineral acid whichever is present.

2. Either total hardness or each of the hardness minerals calcium, magnesium, iron, etc.

3. Alkalies, sodium and potassium.

4. Acid anions, chlorides, sulphates and if desired, the nitrates.

All of these should be determined in order that the chemical results can be checked. However, any one of the last three might be left out of the chemical analysis and its amount ascertained by differences.

Trilinear Plotting.

The trilinear method of plotting used by Hill permits classifications based on separation of the alkaline earth cations and the acid anions, each into two groups. The trilinear chart used is shown in Figure 32. Percentage distribution of equivalent concentrations of cations are plotted in the lower left triangle and anions in the lower right hand triangle. Nitrates are grouped with chlorides but since the amount of nitrates is ordinarily very small this is not important. Iron and other metal ions must be grouped either with calcium or magnesium. The points plotted in the lower triangles are projected parallel to lines AB and BC to their point of intersection in the upper triangle. If the alkalies are greater than the chlorides the points fall in the upper left triangle and if less in the upper right triangle.

On shifting the ion concentration points together into one or the other upper triangles a new set of significant interpretations may be made. The three directions of plotting for the two upper triangles are indicated by Z_1, Z_2, and Z_4 and Z_1, and Z_3, and Z_4 at the vertices opposite the zero base lines.

In the upper left triangle the Z_1 axis indicates the amount of chloride and nitrate and since these are less than the sodium and potassium they may be considered as representing sodium and potassium chlorides and nitrates. The Z_4 axis shows the amount of calcium and magnesium and since there are more than enough carbonate and sulphate ions for these hardness chemicals, the calcium and magnesium may be considered as representing the calcium and magnesium carbonates and sulphates. The Z_2 axis, therefore, indicates the remaining salts, i.e., the sodium and potassium carbonates and sulphates.

In the upper right triangle Z_1 indicates the sodium and potassium ion and since there is now an excess of chlorides and nitrates the sodium and potassium may be considered as representing the percentage of sodium and potassium chlorides and nitrates. The Z_4 axis now shows the carbonates and sulphates and since there is more than enough calcium and magnesium to combine with these, the Z_4 axis may be considered to represent calcium and magnesium chlorides and nitrates.

Summarizing the above two paragraphs the four following geochemical groups are obtained.

Group Z_1 -- The common salt group, sodium and potassium chlorides and nitrates.

Group Z_2 -- The alkali group, sodium and potassium carbonates and sulphates.

Group Z_3 -- The Bittern group, calcium and magnesium chlorides and nitrates.

Group Z_4 -- Hardness group, calcium and magnesium carbonates and sulphates.

Most natural surface and ground waters fall in the upper left triangle, that is they contain the alkali group, while waters contaminated with sea water or acid drainage waters contain the bittern group which places them in the upper right triangle. Hill uses classifications based on the subdivisions of the upper triangles. Since the significance of these classes is evident from a study of Figure 32, they are not described.

The geochemical location of a point representing a mixture can be used to determine the proportion of waters mixed, as was the case with the rectilinear method of plotting. Free acid cannot be represented in this plotting scheme. The graph is somewhat more complicated than the rectilinear one and requires complete ionic chemical analysis.

For the trilinear plotting the following analyses must be made.

Alkalinity
Calcium
Magnesium
Iron
Sodium
Potassium
Chlorides
Sulphates, and
Nitrates

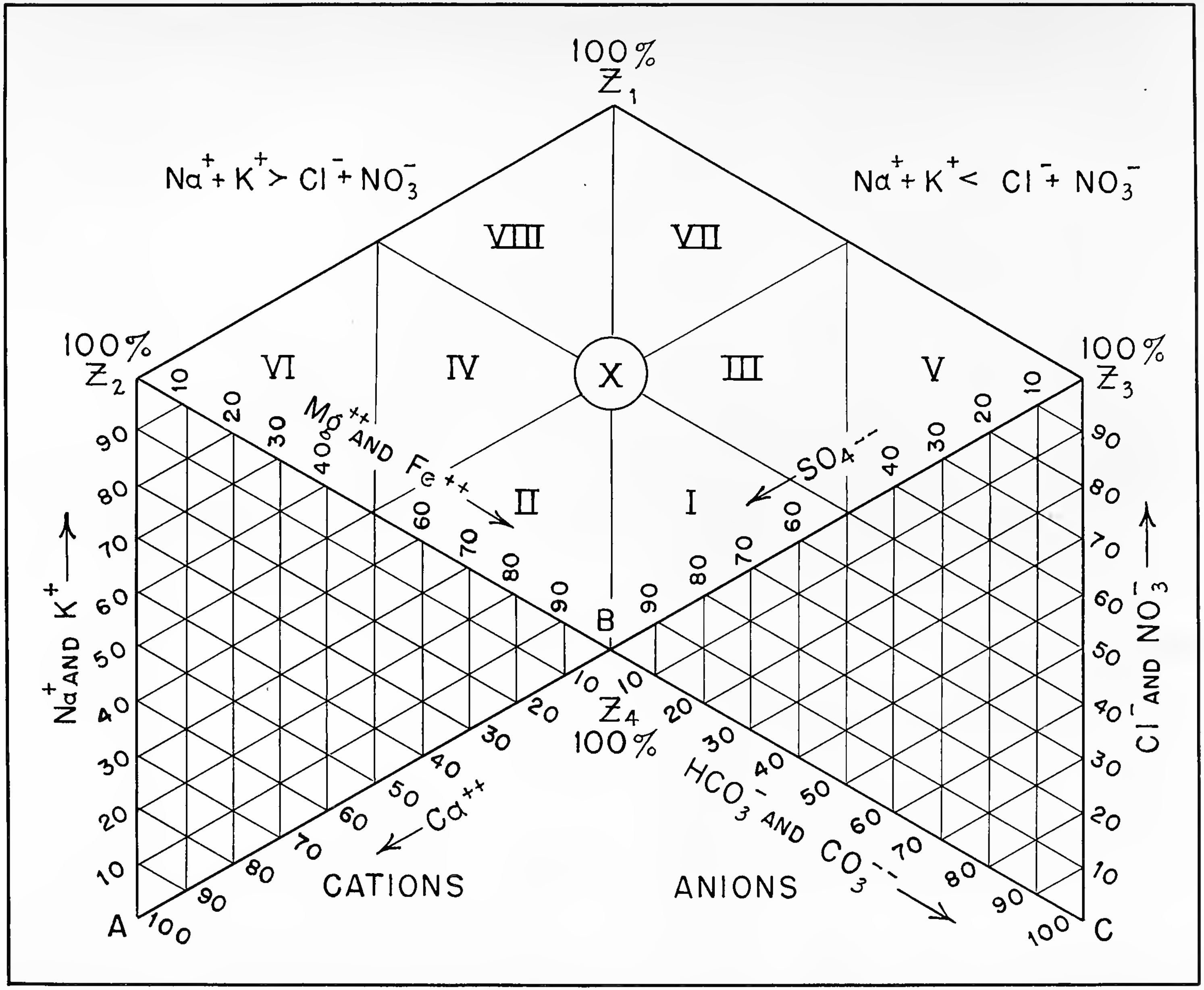


Fig. 32 Trilinear Geochemical Graph.

APPENDIX IX

Computations Pertaining to Well Grouting Methods

A. Rise of Grout Inside an Air Vented Capped Casing

Determining the instantaneous level of grout within the casing during grout pumping when the method described on page 83 , is used presents a nice problem in calculus involving the rate of pumping, the sectional areas of the casing and the annular space, the manner in which the air is compressed (probably isothermal) and the densities of the fluid columns involved.

The level of grout in the well when the annular space has been completely filled with grout can be computed without difficulty as follows:

Assuming D as the depth of the bottom of the casing, the initial air pressure required to expell the water is

$$P_i = 0.433D \text{ lb/sq. in.}$$

The pressure registered on the air gage after grouting will be determined by the difference in heights of grout columns inside and outside the well. If the depth to the grout level inside the casing is H the final gage pressure will be:

$$P_f = 0.857H \text{ lb/sq. in.}$$

Assuming isothermal compression and calling atmospheric pressure P_a Boyles law gives:

$$(P_i + P_a) \; V_i = (P_f + P_a) \; V_f$$

Let A = area of the casing, then

$$V_i = AD \text{ and } V_f = AH$$

Substituting these values of V and P in the equation for pressure times volume is a constant and using 14.7 lbs per square inch for atmospheric pressure:

$$(0.433D + 14.7) \; AD = (0.857H + 14.7) \; AH$$

$$0.433D^2 + 14.7 = 0.857H^2 + 14.7 \; H$$

For any given value of D the quadratic in H can be readily solved. For example, if D = 100 feet.

$$0.857H^2 + 14.7 \; H = 4330 + 1470$$

completing the square

$$H^2 + 17.1\ H + 73.5 = 4330 + 1470 + 73.6 = 5873$$

$$(H + 8.6) = 76.6$$

$$H = 68 \text{ feet}$$

Thus the grout will rise 32 feet inside a 100 foot casing unless the air pressure is raised as the grout pumping continues. The initial and final pressure gage readings will be:

$$P_i = 0.433 \times 100 = 43.3 \quad \text{lbs/sq. in.}$$

$$P_f = 0.857 \times 68 = 58.2 \quad \text{lbs/sq. in.}$$

Forces on a Liner Pipe During Grouting.

An example is worked out here to show the computations that should be made in order to determine the net bouyant force on the liner pipe when using the packer pipe method of grouting.

Assume an 8" liner pipe 200 feet long to be grouted into the bottom 200 feet of 12 inch hole in a 500 foot well. The upper 300 feet of the well is assumed to have been cased and cemented before the hole was continued downward.

The weight of the casing and liner pipe is 25.55 lbs. per ft. The weight of the 2 inch grout pipe is 3.75 lbs. per foot. The total weight of liner, packer and grout pipes is therefore:

$$500 \times (25.55 + 3.75) = 14{,}600 \text{ pounds.}$$

Cross sectional areas of the liner and grout pipes are:

OD area of Liner	=	0.406	sq. ft.
ID area of Liner	=	0.356	sq. ft.
OD area of Grout	=	0.031	sq. ft.
ID area of Grout	=	0.023	sq. ft.

The minimum weight of liquid between the grout and the liner and packer pipe during grouting is that of a full water column. It is

$$(0.356 - 0.031) \times 500 \times 62.4 = 10{,}000 \text{ pounds.}$$

The upward pressure on the bottom of the packer plug due to static weight of the grout is:

$$(0.406 - 0.023) \times 500 \times 123 = 23{,}000 \text{ pounds.}$$

To these static forces must be added the dynamic forces due to friction on the pipe walls during pumping. If the dynamic loss of head is assumed to be 60 pounds per square inch in the grout pipe and 30 pounds per square inch in the annular space around the liner, the downward force on the grout pipe is

$$0.023 \times 12 \times 60 = 16.6 \text{ pounds}$$

and the upward force on the liner and packer is

$$(0.406 - .23) \times 12 \times 30 = 138 \text{ pounds.}$$

The dynamic forces are therefore negligible when compared with the weights of the pipe and the liquids.

Thus in this case during pumping the total downward force is 24,600 pounds and the upward force is 23,600 pounds and there exists the very slight margin of 1000 pounds to hold the packer and liner down.

When the grout line is disconnected and flushed the balance will be as follows assuming that the grout line is not suspended on the packer pipe at the top of the well.

The weight of packer and liner is:

$$500 \times 25.55 = 12{,}800 \text{ pounds.}$$

The weight of water is:

$$0.365 \times 500 \times 62.4 = 11{,}100 \text{ pounds.}$$

The pressure on the bottom of the liner pipe and plug is

$$0.406 \times 500 \times 123 = 25{,}000 \text{ pounds.}$$

The net force is 1,100 pounds upward and for safety the packer pipe would have to be securely anchored down.

If in this case the liner and packer were lowered on the grout pipe the stress in the grout pipe assuming maximum thread depth at end of couplings equal to 25 per cent of the pipe thickness, would be:

$$S_{max} = \frac{14{,}600}{0.75 \times 2 \times (2.375 - 2.067)} = 10{,}000 \text{ lbs per sq. in.}$$

This would certainly be close to the upper stress limit that could safely be placed on the grout pipe and moreover considerable care would have to be used in designing the plug connection at the foot of the liner to assure adequate strength at this point.

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